GRAY'S PLUMBING DESIGN AND INSTALLATION

WM. BEALL GRAY

Gray's Plumbing
Design and Installation

A VERITABLE Encyclopedia of modern practice based on work done by the author and other experts in every branch of the plumbing and allied trades and covering approved practice in every part of the country. There are 500 original drawings many of which illustrate two or more different problems. For quick reference it is divided into five sections, i. e.: I—Explaining Arithmetic, Geometry and Trigonometry so simply that the mechanic can understand it; numerous Tables, Rules, etc. II—Water Supply Work and Its Installation. III—Plumbing Fixtures, Their Merits and the Work of Setting Them. IV—Soil and Waste Systems, Sewerage and Drainage Work and Methods of Disposal. V—Miscellaneous Subjects of Importance to Plumbers and Kindred Craftsmen. 28 Pages of Double Column Index Facilitates Quick Reference to Any Item.

By WILLIAM BEALL GRAY

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PREFACE

This volume is offered with the firm conviction that it is needed and will be welcomed by the majority of plumbing craftsmen.

It is desired to have the reader know at the outset that a mechanic is speaking,—one who has served on a wide range of work in every capacity afforded by the trade and its interests.

In some respects much of the literature devoted to the trade has not given the most needed help to a large majority, though it has catered all but too well to a minority that was prepared to succeed fairly without it.

Too little has been heard from the competent man on the job. He has not sufficiently laid before the craft in his own way the problems he met in practice; how he overcame them; with what result; how such procedures might be applied to the general run of kindred problems, etc. He has not told what line of data he found deficient, unwieldy or absent; what he successfully adapted and appropriated to his own use from the general cycle of knowledge, and how he did it. If he has made rules from practice that work, sifted the good out of suspicious looking engineering formulae, expanded some mathematics of the trade to a point where his graded-school helper could understand and apply it, or figured out the short cut to results from some processes that the mechanic's leisure is too short to apply, he has left his brethren too much in the dark about it.

The conditions under which the mass of craftsmen secure and execute their work in different sections of the country are vastly different; seventy-five per cent. of the men interested in the business must settle their own problems from start to finish because there is none other at hand competent to design the work and point out the specific things to be done in order to get desired results. It is to be hoped that it will be ever so for it is this state of affairs that has contributed most to making the plumbing of this country superior to that of any other.

It was with the above in mind that the author has worked from first to last.

Realizing that many engaged in the business will not have an adequate library of other books to refer to, one of the five sections of this work has been devoted to such arithmetical and other formulae, tables, rules and directions as will enable the reader to verify any statement or refer to, in the book in hand, any needed rule or data not given in the

immediate text. This saves time, is very convenient, and gives the work the advantage of acting, in a measure, as the beginner's whole technical library; he does not have to wonder *what* book contains the desired information, under what head he will find it, nor whether he has a book at all that will enlighten him, and if not, where he can borrow or buy one,—he has only to consult the book in hand and if the point is even remotely akin to plumbing, he will find help. In this way much data that would clog the text if presented in its body and leave the work unintelligible if given no place at all, is given unprecedented prominence and treatment in order that it may serve with something like its normal value as a necessary auxiliary that has been too long unappreciated.

Comparatively little attention has been given to tedious details of routine manual operations. Such knowledge is ordinarily gained too fast in practice, in the sense that it tempts the young man to exploit his manual skill for wages, which being mistaken for the goal unqualified, improvement ceases.

No effort has been made to present pictures of nor to minutely describe market goods,—market forms and names are continually changing and the better plan has been adhered to in illustrating and describing principles which the reader will recognize and understand the action of, no matter what is claimed by makers nor in what form their goods are made.

The reader is assured that successful practice is behind every statement made in the book, and care has been taken to give examples of what may be and has been done in actual practice. He may therefore know that, however many other ways a thing can be done or might be accomplished, there is no doubt about *the* way described in this volume.

W. B. GRAY.

Louisville, Ky., Jan., 1916.

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PART I

CHAPTER I

The Scope of Plumbing and its Natural Divisions

Although, in justice to both the reader and the author, the preface of a book should be read first, many fail to do so,—not realizing that a book should contain nothing but what is there for a good reason and that while the subject matter may be in perfect sequence, the "beginning" is not the same place for all readers. These facts prompt a departure in presenting in the fore part of this chapter, a story and some lines that are really introductory matter.

There is a story of a Spring, a Shade and two Graves by a highway. Many passers quenched their thirst at the spring, rested in the shade, read the inscriptions on the headstones, wondered at the singularity of the wording, and continued their journey unenlightened. But, there trudged along that highway one hot day, a philosophic stranger. It was at noontime and he was tired, thirsty and hungry; he saw the spring, drank, and ate his luncheon in the shade. While resting, he noticed the graves and read the epitaphs. One said: "Here lies the body of John Smith, died," etc. The other said: "Here lies the soul of James Smith, died," etc. Being a thinker, the stranger reasoned why? thus: There is nothing without reason; an epitaph is not a frivolous matter; there must be a good reason; John died first; his God was money; they were two bachelor brothers who out-lived their relatives, so there was no one to interfere; John's soul being in his hoardings, the brother buried John's treasure with the body and supplied the very appropriate epitaph which neighbors looked upon as an eccentric whim of the living brother. When James died, the neighbors buried him beside his miser brother, and wrote an epitaph to their liking. There was less to escheat to the county than was expected but the lack of treasure was attributed to James' open handed charity, and no search was made. Reasoning thus, the stranger said there is money in John's grave; he followed up his judgment with a pick and shovel and the treasure was his.

Now, the size of the treasure in this book, for a plumber or pipe-fitter of any class, depends upon how much thinking and digging he has done or is willing to do for it,—it's there; all you have to do is to go after it,—no matter who you are nor what you already know, so long as you are a pipe-fitter.

For those who have mastered the business there is the data and

rules; much assembled from many sources; much new; much in more convenient shape than ever before, all in one book, saving the time and avoiding the annoyance of referring to a dozen other books, together with the advantage of reviewing the various features of the business as seen by another, perhaps from an entirely different point of view from that which the reader has been accustomed to think. Some things which we think our convictions are closed on appear very different when we hear the other fellow's side of the question, especially if the other fellow has given the subject much conscientious thought and expresses his honest opinion and knowledge for no other purpose than to disseminate the truth as his thought and experience reveals it.

For the beginner the whole matter, from the ground up, is laid out and disposed in the manner shown by the table of contents.

A plumber would find it hard to write much of plumbing without saying something of the status of lead in the trade to which it contributed a name,—a theme which many have failed to do justice.

Diminishing use of lead first gave rise to a groundless fear that plumbing was doomed to swell the list of dead and dying trades. The skill of manipulating lead and solder was at one time too nearly all that many counted in reckoning what constituted a plumber. Mature lead workers were averse to innovation. Boys did not take the proper pride in lead work when it began to lose ground. A different class of workmen resulted for they were inducted into the business and taught under less rigid rules with respect to the sort of future to look forward to. The loss of prestige suffered by lead made all concerned care less for the time-honored skill of the plumber in lead work. The boys were indifferent to mastering solder work and equally more alert to every circumstance promising to strengthen their hold upon a calling fast losing the distinguishing feature of its past. For these reasons the younger element thirty odd years ago was never so well intrenched behind the skill that had previously constituted a plumber, and was quick to welcome the advent of other materials answering for lead and to further their use in any form. The older men were not skilled in fitting nor favorable to the use of lead substitutes which demanded of them the receptiveness and versatility of youth. So the calling came by easy stages almost to the point of having the name without the substance before the result of reflex opinion was felt in the way of installation of lead, brass or iron according to fitness for the specific service.

Should the now limited use of lead in "Plumbing" be further restricted in the future, which is unlikely, its peculiar fitness for many purposes in plumbing would remain unchallenged and the plumber, in spite of all the opposed prejudices of the past, would still regard this important element with a feeling akin to reverence. It is the grandfather of both his vocation and appellation, the termination "*er*" being

substituted in the technical name of lead, *plumbum*, to indicate the personal agency,—"'Plumber',—one who works in lead."

All religious and political reformations have been occasioned by abuse in some form; restoration of a trade feature may proceed from the same cause. And, though lead lost prestige through employment of the more suitable material afforded by progress in other lines, rather than by degradation, substitution was in some directions carried beyond discretion.

This, the present, is the hybrid stage of the business,—iron is *dominant;* lead recessive; in the hybrid offspring, figuratively speaking, Mendel's percentage of lead work will reappear in service according to its merit for the purpose. There is, unfortunately, no constant or definite measure of fitness. In particular instances it may be wise to adapt the structure instead of the fittings. Intelligent adaption will always be the ultimate solution regardless of the branch of building suffering interruption, alteration or substitution. It may be our turn today; the other fellow's tomorrow.

Plumbing is but a feature of the structure and though an important one, its craftmen should be reasonably flexible in the interest of general fitness, whether the subject be principle, price, material, or the occasional sacrifice to local expediency. The safe course is to follow honest convictions whether the road seems, at the time, to lead to or from money.

Regarding the natural divisions of plumbing work, collecting, storing and conveying water to fixtures belongs to the *supply work* end of the business,—the first requisite. If for a private job, it may be within the province of the plumber to reject, or, purify the supply by filtration, coagulation, aeration, or some combination of these processes.

At the points of usage, various types of pollution take place, and for sanitary convenience suitable fixtures, their fittings, and proper installation become a second feature in plumbing a house.

Means of waste disposal must be supplied. House waste, soil and vent pipes, traps, etc., to protect the occupants of the building, generally termed "roughing in" work naturally constitutes a third division of a job,—utilizing the water as a carrier of offal.

A fourth, final, feature to every job, no less important than the others, is the outside sewer work, designed not merely to serve the purpose for the individual job but to accomplish the end without danger to the health of neighbors. The disposal may be creditably taken care of in several ways, according to local conditions,—by public sewer, by surface oxidation or by irrigation, plain or by septic method. All but the last mentioned do well with the sanitary and storm water drainage either separate or combined; storm water should be isolated from small septic plants.

It does not follow that the sequence of installation of work shall

conform to the order in which the features have just been named,—the structure, purpose, location, or progress of various interdependent lines may determine the order of work. What has been said, however, suggests the breadth of swath which a plumber of today may prepare to cut with credit to himself and the craft.

CHAPTER II

Properties of Substances

Table I sets forth, roughly in some respects, certain properties of a few familiar substances likely to be of more than ordinary interest to the plumber. It is not possible to make such a table entirely acceptable because either no one source has worked out the figures in harmony or they were obtained under specific conditions requiring endless provisos and explanations that cannot be given space. The data will none the less serve its purpose as given,—furnish the plumber with a general idea of the traits of many materials with which he works contrasted so he may quickly make intelligent comparisons, leading often to a clearer understanding of what is to be contended with in his work.

Elements are given at the left and compounds and alloys at the right of the table. All things consisting of more than one element are compounds; compounds like metals melted together are called alloys. Chemical compounds are definite quantities of the elements composing them, held together by chemical affinity as, for example, sulphuric acid, the result of two component compounds so uniting, and in which two atoms of hydrogen have united with one of oxygen as one component, while three atoms of oxygen has been embraced by one of sulphur as the other, the uniting of the two producing sulphuric acid, H_2SO_4, thus:

$$\left.\begin{matrix}H\\ \\H\end{matrix}\right\}-O-H_2SO_4-S-\left\{\begin{matrix}O\\-O\\O\end{matrix}\right.$$

This will be better understood by referring to valence of sulphur, oxygen and hydrogen in the column of quantivalence in Table I. It is there seen that an atom of hydrogen can hold but one atom of other elements; that an atom of oxygen can hold two atoms (see symbol of water) of other elements, something as though the atom had will power and two hands, each hand capable of holding one atom of any other elementary substance; that sulphur atoms have a power of affinity (valence) varying (III, IV and VI) with the condition under which it finds its affinities, etc.

Air is as definite in the percentage of its elements as a chemical compound but it is a *mixture.* In the table no notice is taken of its impurities, or the small amount of Argon, an element, always present.

The relative weights of elements in a chemical compound do not vary. The percentages by weight, of the constituents of water are thus always 0.88889 of oxygen and 0.11111 of hydrogen; those of lime, 0.28571 of oxygen and 0.71429 of calcium, and so on.

Chemical symbols of elements stand for the name; in compounds, by stringing them together and indicating the atoms of each by figures

Table I. Some Properties of Familiar Substances

Elements Name	Chem. Symbol	Valence	Atomic Wgt.	Specific Gravity	Specific Heat	Latent Heat of Fusion B.t.u.	Melts at deg. F.	Linear Expansion of Unit Length per deg. F.	Weight Pounds 1 cu. in.	Weight Pounds 1 cu. ft.
Aluminum	Al	IV	27.08	2.6	.212	....	1157	.00001234	.095	....
Antimony	Sb	III, IV	120.0	6.71	.0508	....	1000	.00000627	.24	....
Bismuth	Bi	III, IV	207.5	9.82	.03	22.7	493	.00000975	.35	....
Calcium	Ca	II	40.0	1.57	....	....	....	....	....	....
Carbon	C	IV	11.97	3.5	....	....	....	....	....	....
Chlorine	Cl	I, V	35.4	2.45	.121	....	....	....	....	....
Copper	Cu	II	63.3	8.95	.095	....	1930	.0000088	.32	....
Gold	Au	I, III	196.7	19.32	.0324	....	2280	.0000078	.69	....
Hydrogen	H	I	1.0	.000084	3.2936	....	....	....	....	.00559
Iron	Fe	II, IV, VI	55.9	....	....	....	....	....	....	....
Iron, cast	...	....	....	7.5	.123	50	2250	....	.27	....
Iron, wrought	...	....	....	7.86	.112	....	2000	.00000648	.28	....
Steel	...	....	....	7.83	.118	....	2500	....	.29	....
Lead	Pb	II, IV	206.4	11.37	.0314	9.66	608	.0000157	.41	....
Mercury	Hg	II	199.8	13.59	.33	3.6	39.4	....	.49	....
Nickel	Ni	II, IV	58.6	8.9	.1086	....	....	.0000069	.32	....
Nitrogen	N	III, IV	14.	.00118	.24	....	....	....	....	....
Oxygen	O	II	15.96	.00135	.22	....	....	....	....	.0892
Phosphorus	P	I, III, IV	31.10	2.01	.19	9	112	....	....	....
Platinum	Pt	II, IV	194.3	21.5	.0324	....	3250	....	.77	....
Potassium	K	I	39.0	.87	....	....	144	....	....	....
Silver	Aq	I	107.7	10.53	.056	38	2000	.0000108	.38	....
Sodium	Na	I	33.	.978	....	....	208	....	....	....
Sulphur	S	III, IV, VI	32.	2.05	.2	16	228	....	....	127
Tin	Sn	II, IV	117.4	7.29	.056	25.6	446	.0000116	.26	....
Zinc	Zn	II	90.4	7.15	.093	50.6	750	.000014	.25	....

Compounds Name	Chemical Symbol	Specific Gravity	Specific Heat	Weight Pounds 1 cu. in.	Weight Pounds 1 cu. ft.	Linear Expansion of Unit Length per deg. F.
Air—32 deg. F	$N_{79}O_{21}$	.00122	.238	....	.0807	....
Alcohol, gr	C_2H_5OH	.80	.652	....	.575	....
Ether, sulphuric	$(C_2H_5)_2O$	.72	.503	....	....	....
Acid, muriatic	HCl	1.2	....	....	....	....
Acid, nitric	HNO_3	1.22	.343	....	....	....
Acid, sulphuric	H_2SO_4	1.85	.33	....	....	....
Turpentine	$C_{10}H_{16}$	.87	.416	....	54.3	....
Linseed oil	....	.94	....	....	....	....
Litharge	PbO	....	....	....	....	....
Red lead	Pb_3O_4	....	....	....	....	....
Brick	....	....	.20	....	125	.000003
Cement, hyd	....	....	....	....	78	.0000059
Glass	$NaCa+SiO_2$	2.89	.198	....	180	.0000045
Lime stone	$CaCo_3$	3.15	.217	....	197	....
Marble	....	2.68	.269	....	168	.000005
Masonry	....	2.24	.20	....	140	.0000025
Porcelain	....	....	.17	....	....	....
Sand	....	....	.195	....	105	....
Ice	H_2O	9.22	.504	....	57.5	....
Steam—212 deg. F	H_2O	.0006	.847	....	.038	....
Water—62 deg. F	H_2O	1.0	1.0	....	62.3	....
Charcoal	C	.44	.24	....	27.5	....
Coke	C	1.0	.20	....	62.5	....
Pine wood, wh	....	.55	.65	....	34.6	....
Oak wood	....	.86	.57	....	54	....
Brass	CuZn	8.1	.094	.29	....	.00000597

set inferior, the constituent elements and percentages are easily indicated, however complex.

Atomic weight is merely the weight of an atom of a substance compared with that of an atom of hydrogen. The relative weights are given in the table.

Specific gravity of a substance means its weight compared with that of an equal bulk of pure water. Sp. Gr. is found by deducting the weight of a body weighed suspended in water from the weight of the same obtained by weighing it in air and dividing the difference into its weight in air,—the quotient so obtained is the specific gravity of the substance.

Specific heat expresses the relative amount of heat needed to warm the substance considered as compared with that required to raise through one degree an equal weight of water. Water being the standard, and 1 B.t.u. being capable of raising 1 lb. 1 deg. F., it is seen by the table, that the heat which will raise a given weight of water to a certain temperature, will, if applied to sulphur raise five times that weight to the same temperature; that is, 1 B.t.u. will raise 1 lb. of sulphur 5 deg. F. or 5 lb. of sulphur 1 deg. or, 1 lb. of iron 9 deg. or 9 lb. of iron 1 deg. F.

Latent heat expresses the quantity of heat absorbed or given out when bodies liquify, solidify, melt or vaporize. This amount of heat, so made latent or sensible, differs for different substances and is not registered by thermometers. In changing from ice at 32 deg. F. to water at 32 deg. F. 144 B.t.u. are absorbed, and in changing from water at 212 deg. F. to steam or vapor at 212 deg. F. 965.7 B.t.u. are absorbed per pound, but the thermometric temperature does not alter while the change of state is in progress. In reversing the state, a like quantity of heat is given off without a change of temperature being shown by a thermometer immersed in the liquid. The amount of heat so made latent by some other substances is shown in Table I.

A better understanding of some of the data given, and thereby the nature of materials, is gained by a brief review of the theory of matter. Substances are made up of molecules. A molecule is composed of atoms. The molecule is exceedingly small, and the *atom* was long considered the ultimate particule,—the smallest particle of matter that could exist,—not existing alone but associated with other atoms which combined constitute the molecule. The molecule is the smallest quantity of matter capable of existing by itself. The molecule can be chemically separated into atoms. A molecule of any certain substance always contains the same number of atoms of the same kind and weight. An element is something not made up of different materials,—not a mixture and not a chemical compound. All substances which human skill has been unable to separate into two or more kinds of matter are supposed to be elements and are so catalogued.

Since radium has afforded an extended basis for investigation, some scientists have shown that the atom is not the ultimate particle, but that it is the shell for other still smaller particles called corpuscles. These (the corpuscles contained by an atom) have been compared to a few mustard seeds flying about at incredible speed within an immense

balloon. Since the corpuscles act in groups and the groups and number of corpuscles per atom are said to vary in different atoms, it is seen to be probable that the universe is of one kind of matter differentiated by the arrangement of corpuscles in the atoms of what we now take to be elements.

CHAPTER III

Water Data Bearing on Plumbing and Kindred Work

If any one of nature's products can be said to be more important than another, it is water. It is the vehicle which brings all manner of plumbing into service; without it, supply, waste and vent pipes and the fixtures which they serve would have no function as such and perhaps the fixtures would be impossible of manufacture at all, since steam and water power would be impossible and electric current otherwise produceable extremely limited. Even the structures into which to put plumbing, would, if considered only so far as sedimentary materials, rock, marble, cement, lime, sand, etc., is concerned, offer poor habitations for plumbing, but for water. A good dictionary devotes 10,000 words to "water." The life-work of many eminent men have been inadequate to record its story to the last word.

The plumber is wholly dependent upon water for his calling. He is regularly dispensing water to others as a profession. His work aims at conservation of health as well as the convenience of the users. He should therefore be more than ordinarily interested in the composition and traits of water beyond the limit necessitated by manual arts of the trade.

Pure water is a colorless, odorless, tasteless and transparent liquid; consists of two gases: Oxygen, 89 per cent. by weight,—$\frac{1}{3}$ by measure, and Hydrogen, 11 per cent. by weight,—$\frac{2}{3}$ by measure. It is almost incompressible; highly elastic; a poor conductor of heat; a good conductor of sound and electricity; the greatest natural solvent; "soft" as distilled or rain water; "hard," saline or otherwise from lime or other mineral or materials it may have become charged with in percolating through rock strata or earth. It is largely the bulk of vegetable, animal and mineral compounds; does not impart the flavor of salt or other mineral to fish living in seas; to some extent it freezes into pure water ice regardless of the quality of the liquid; furnishes, by evaporation under the sun's heat, the vapor of the clouds for rain, thus keeping up inland supplies; finds its way back to the sea in streams of any length running in any direction,—due to centrifugal force of rotation of the earth which is sufficient even though the arc of course makes the water flow up hill in a sense. Through frost, rain, solvency, weight and travel it is the prime agent of weather in building land, and in making the sedimentary rocks of future ages; it buoys up floating and suspended objects with a force equal to the weight of water displaced by submergence; it is a chemical union, not a mechanical mixture of the component gases.

Its boiling point depends upon the pressure on the surface and therefore, when in open vessels, upon the altitude of the location; boiling point at sea level, under 30 inches barometer and temperature of 60 deg. F., is 212 deg. F., or 100 deg. C.; at 500 feet altitude, 210 deg.; 1600 feet, 209 deg.; 2600 feet, 207 deg.; 3600 feet, 205 deg.; 4700 feet, 203 deg. and 11000 feet, 190 deg. F.,—roughly 600 feet altitude per degree change of reading. Matter in suspension does not raise the boiling point; matter chemically combined or dissolved in it, like salt in solution, does; saturating with common salt will raise the boiling point of common water about 13 deg. F. and much higher boiling points can be obtained by adding calcium chloride. So, there is no danger of the plumber foregoing boiled eggs in high altitudes. Water freezes 32 deg. F. or 0 deg. C. The freezing point of salt water is 32 deg. F. below the freezing point of fresh water.

Water is at maximum density at 39 deg. F. or 4 deg. C.; it is at the same density at 48 deg. F. and 32 deg. F., and, at 0 deg. C. and 8 deg. C.

In cooling, water contracts in volume at a decreasing rate until it reaches its minimum volume at 39 deg. F.; under continued cooling, it expands in volume until it reaches 32 deg. F., the temperature of solidification; then, if the extraction of heat be continued, a thermometer will not indicate the fact until the loss equals the latent heat of fusion for ice at which point further loss of heat will be registered as usual, the ice growing colder than ice, so to speak, and contracting at temperatures below 32 deg. F. *at*, taking the coefficient for linear expansion multiplied by 3 for cubical expansion, something like the rate of .000175 per unit volume per degree F. If the process be reversed, and the ice be warmed and thawed, no thermometer will record the heat absorbed after the ice reaches 32 deg. until the ice is melted, the water and the ice both remaining at 32 deg. until the ice has absorbed per pound the definite amount of heat regularly made latent by fusion,—144 B.t.u. Expansion of water from 39 deg. F. to 32 deg. has a far reaching effect. The length of seasons, water and ground life, vegetation, and liberal flows of temperate water, etc., are greatly dependent upon this singular characteristic of water.

An exception to the rule of the trade that "water will not circulate downward by the application of heat" is furnished by the expansion of water in cooling as stated. When a tank contains sheet ice on the surface of the water, the circulation due to moderating weather is first downward; the expanded water, colder than 39 degrees F., remaining at the top because it is lighter, bulk for bulk, though colder, than the underlying body. In sinking from growing warmer, it, of course, simultaneously lifts warmer water to the region of the ice and thus the reduction of the sheet of ice goes on both from above and below.

The comparative bulks of equal weights of air and water is about

as 800 is to 1. The relative densities of a unit volume of water and its vapor or steam vary with the pressure; at one pound absolute and temperature of 102 deg. the vapor is about 20600 to 1. At atmospheric pressure (14.69 lbs. at sea level) the vapor is 1646 to 1,—over 26 cubic feet to the pound of water; at 50 pounds pressure and 281 deg. F. it is but 520 to 1,—8.3 cubic feet of steam to the pound of water; at 1000 pounds pressure and corresponding temperature, 547 deg. F., the steam is but 30 to 1 and $\frac{48}{100}$ of a cubic foot weighs a pound. Steam being lighter than air, air valves are placed low on steam coils to relieve them of air, instead of at the top as is essential when it is desired to prevent air from impeding a flow of water.

Water weighs 8.33 pounds to the U. S. gallon of 231 cubic, or 294 cylindrical inches,—about 1 pint to the pound, 7.5 gals. or 62.5 lbs. equal one cubic foot; frozen, it weighs 57.5 lbs. to the cubic foot.

Twelve cubic inches of water weigh 0.43 lb. and therefore the suction limit (for *cold* water) with perfect apparatus is 34 feet vertical height, because the atmospheric pressure alone must lift the water into the cylinder,—the sucker can only remove the air pressure over the water; 20 feet is a severe practical lift; over 20 feet the low velocity due to diminished lifting force fills the cylinder too slow. The vertical feet of head of a source of water supply multiplied by 0.43 gives the pounds pressure per square inch of interior surface which the pipe will be subjected to. Pressure per square inch in pounds multiplied by 2.31 converts pounds of pressure into feet of head. Dry snow may be taken as about $\frac{1}{10}$ and wet snow at about $\frac{1}{5}$ the weight of an equal bulk of water.

Water is the standard for finding the specific gravity of heavier-than-water substances, and for liquids. The gravity of any material may be so expressed though hydrogen or air is regular for fluids (gases). Ice weighs 8 per cent. less than an equal bulk of water,—due to expansion in freezing. Water expands from freezing to boiling about 5 per cent., —one gallon in $21\frac{1}{2}$ gallons. $27\frac{3}{4}$ cubic inches weigh one pound. Water has the greatest thermal capacity of any substance except hydrogen. Fresh water is $\frac{1}{40}$ lighter per bulk than ordinary sea water. Excessive rainfalls occur on some of the coast lines; the average fall decreases inland to nothing on some of the arid plateaus. Some 30 per cent. more or less of the fall percolates through the soil, according with topography and strata; it moistens the ground and growth and furnishes the dry-season flow to streams, springs, etc.

From the annual rainfall and seasonal evaporation, water systems, size of collecting sheds, drain pipes, reservoirs, etc., are calculated, and even meager data of the kind is often of great help. Tin, slate and tile roofs shed nearly all the water that falls on them; shingle roofs when dry practically absorb a light shower.

In ponds and reservoirs, without inflow, the whole annual rainfall may be held and counted on, with allowance for annual evaporation, the mean for which, in open bodies exceeds 40 inches depth. Winds and timber affect evaporation,—the rate for quiet air being only about 11 inches per season. Evaporation is greatest during the season of least fall and at least half the yearly demand should be stored as surplus during months of heavy fall. In shallow unfed reservoirs the ratio of surface to depth is too great to preserve supply to advantage.

The mean annual distribution of rain may be inferred from the following, representing states divisions: New York, 44; Florida, 54; Kentucky, 47; Ohio, 40; Minnesota, 30; Utah, 18; California, 17; Oregon, 46; and Colorado, 14 inches. Lakes, water sheds, roof collection, surface and underground streams, and pumped or artesian wells tapping water-bearing strata are the principal sources of water supply.

An artesian well is self-flowing, from gas pressure or from a static head due to imprisoned water banking in favorable syncline strata sufficiently denuded for percolation from the surface, or otherwise supplied,—the water strata being necessarily contained in and capped by impervious materials.

The purest ground source of water is probably the springs of granite districts. Water charged with minerals are either chalybeate, saline, sulphurous, carbonated or alkaline and none of them are fit for culinary uses. Reagents produce no precipitate or cloudiness in pure water. Any pharmacist will supply a reagent for the suspected impurity and give directions for use.

CHAPTER IV

Heat of Steam and Water

The heat contained in water at any ordinary temperature amounts to about one British Thermal Unit for each degree Fahrenheit, being about, reckoned from zero, F.,—100 B.t.u. at 100 deg. F.; 200$\frac{3}{4}$ B.t.u. at 200 deg. F.; 282 B.t.u. at 280 deg. F., and 380 B.t.u. at 375 deg. F. The latter two temperatures are above that to which water is usually heated, as water, even for house-heating purposes and may be reckoned as the heat of the liquid under steam pressure corresponding to the temperatures given. The loss or gain from cooling or heating water being so nearly 1 B.t.u. per pound of water, per deg. F. change of temperature for the range of common working temperatures, it is assumed for all calculations of common practice, that 1 B.t.u. is added or extracted per pound of water for each F. degree change of temperature. Thus: if 12 gals. of water (100 lb.) are raised from any temperature F. to 1 deg. higher, say from 60 to 61 deg. F., 100 B.t.u. have been added; if raised 10 deg. F., 1000 heat units would be added, and if 100 lb. water are to be raised 100 deg. F., say from 60 to 160 deg. F., 10,000 heat units will be required. If heat is abstracted from water, as by radiation, by heating water with water, or by the equivalent action of drawing from a storage tank warm water which is immediately replaced, by the pressure, with colder water, the cooling of the mass of water is proportional to the heat withdrawn.

The amount of fuel required directly or through converting its result (as in transmitting the heat of steam to water) is according to the thermal value of the fuel; if the fuel is good coal with 14000 B.t.u. per lb., and 9000 B.t.u. (a high per cent. of efficiency for ordinary work) are assumed to be effective, transmitted the efficiency is 64 per cent., and 1$\frac{1}{9}$-lb. of coal would be required to raise 100 deg. F. the temperature of 12 gals. of water as mentioned above.

It is in the line of data above given that lies the basis upon which begins the proportioning of all steam and water heating apparatus. Many elements are ultimately involved in one way or another, so that the designing is often a work of extreme intricacy in order to have each feature simply adequate to the duty imposed on it by the others. The amount of heat required calls for a certain amount of fuel to be consumed. Fuel consumption necessitates considering the kind of fuel that can or will be used; its thermal valve; the rate at which it should be consumed and the draft possible or probable. These affect the size of ash-pit combustion chamber, doors, flues and smoke passage, or such

Table II. Pressures, Temperatures and Heat Units of Water and Steam

(1) *Pounds Absolute Pressure in Black Figures and Gauge Pressure in Light Face Figures	(2) †Vacuum in Black Figures and Gauge Pressure in Light Face Figures in Inches of Mercury	(3) ‡Temperature F. deg. Also take as No. B.t.u. per Pound of the Liquid above Zero	(4) Latent Heat of Saturated Steam or Vapor	(5) *Gauge Pressure Agreeing with Temperature Given	(6) Temperature in F. deg. for the Pressure Given	(7) B.t.u. per Pound of the Liquid for the Temperature Given	(8) Latent Heat of the Steam—B.t.u. per Pound for the Temperature Given
.09	**29.75**	32	1091.7	21.3	260.83	262.52	930.96
.12	**29.66**	40	1086.1	22.3	262.45	264.18	929.80
.176	**29.56**	50	1079.2	23.3	264.04	265.80	928.67
.254	**29.40**	60	1072.2	24.3	265.59	267.38	927.56
.36	**29.19**	70	1065.3	25.3	267.12	268.93	926.47
.50	**28.90**	80	1058.3	26.3	268.61	270.46	925.40
.69	**28.50**	90	1051.3	27.3	270.07	271.95	924.35
.943	**28.**	100	1044.4	28.3	271.50	273.41	923.33
1.0	**27.88**	102	1043.	29.3	272.91	274.85	922.32
2.	**25.85**	126.26	1026.	30.3	274.29	276.26	921.33
3.	**23.83**	141.62	1015.2	35.3	280.85	282.96	916.63
4.	**21.78**	153.07	1007.2	40.3	286.89	289.15	912.29
5.	**19.74**	162.33	1000.7	45.3	292.52	294.91	908.24
6.	**17.70**	170.12	995.2	50.3	297.77	300.30	904.46
7.	**15.67**	176.91	990.5	55.3	302.71	305.37	900.89
8.	**13.63**	182.91	986.2	60.3	307.38	310.16	897.52
9.	**11.60**	188.31	982.5	65.3	311.81	314.71	894.33
10.	**9.56**	193.24	979.	70.3	316.02	319.04	891.28
11.	**7.52**	197.76	975.75	75.3	320.03	323.17	888.37
12.	**5.49**	201.96	972.80	80.3	323.88	327.13	885.58
13.	**3.45**	205.88	970.	85.3	327.57	330.93	882.91
14.	**1.41**	209.56	967.5	90.3	331.11	334.58	880.34
14.7	**.0**	212.	965.7	95.3	334.52	338.10	877.86
0.3	.61	213.02	965.	100.3	337.81	341.50	875.47
1.3	2.65	216.29	962.65	105.3	340.99	344.78	873.15
2.3	4.69	219.41	960.45	110.3	344.07	347.97	870.91
3.3	6.73	222.37	958.34	115.3	347.05	351.05	868.73
4.3	8.77	225.20	956.34	120.3	349.95	354.05	866.62
5.3	10.81	227.91	954.41	125.3	352.76	356.96	864.56
6.3	12.85	230.51	952.57	130.3	355.50	359.80	862.56
7.3	14.89	233.01	950.79	135.3	358.16	362.55	860.62
8.3	16.93	235.43	949.07	140.3	360.74	365.24	858.72
9.3	18.97	237.75	947.42	145.3	363.27	367.86	856.87
10.3	21.01	240.00	945.82	150.3	365.74	370.42	855.06
11.3	23.05	242.17	944.27	155.3	368.15	372.93	853.29
12.3	25.09	244.28	942.77	160.3	370.51	375.38	851.56
13.3	27.13	246.32	941.32	165.3	372.82	377.78	849.86
14.3	29.17	248.31	939.90	170.3	375.08	380.13	848.20
15.3	31.21	250.24	938.92	175.3	377.29	382.42	846.58
16.3	33.25	252.12	937.18	180.3	379.45	384.67	844.99
17.3	35.29	253.95	935.88	185.3	381.57	386.88	843.43
18.3	37.33	255 73	934.60	190.3	383.65	389.05	841.89
19.3	39.37	257.47	933.36	195.3	385.67	391.17	840.39
20.3	41.41	259.17	932.15	205 3	389.73	394.16	838.63

* For absolute pressure above atmosphere, add 14.7-lb. to the gauge pressure.

† Black figures give vacuum in inches of mercury corresponding to pounds absolute pressure, given in black face figures. Light figures are inches of mercury equal to gauge pressure given opposite. For even pounds G.P. deduct 0.61,—2.04 in.=1-lb., .204=1/10-lb.

‡ Considering temperature degrees numerically, No. B.t.u. contained exceed it by 1.66 at 20.3-lbs. G.P., at which temperature=259.17, and B.t.u.=260.83, or 1.66 *more*, gained gradually from zero. The temperature was allowed to stand for both, in order to save space.

of these as may be a part of the heater in hand. The rate at which different types of heat-absorbing surfaces will take up heat affect some of the foregoing elements and demands, as well, a proper relative proportion of the different types of surface. To these questions is added that of circulating the water contents to the end of getting the greatest amount of heat from the fuel used. These points are mentioned not as a preliminary to any discussion of heater construction, but to suggest uses to which Table II may be put in solving problems of kind and size of heater, amount of surface of water-backs, fire and steam coils, etc.

In making up the table, the object was to associate such kindred data as the plumber would most need on the subject, in a way to get it on one page, and so disposed as to make it the most useful. To do this best, portions of the work of several authorities were embraced and the table does not, perhaps, match up throughout as well as though all of it was from one source, though the best authorities do not *precisely* agree as to the sensible and latent heat of water and steam. Great precision, however, in the light that scientists regard errors, is of so little importance to the trade that not only could the greatest error of the present table be ignored, but even the three odd *tenths* of the gauge pressure could be dropped and the temperature and heat units read as for even pounds without appreciable difference in the result. The work of Lardner and Loewy, Prof. Carpenter, Weisbach, and Porter was consulted.

Column 1 of Table II gives absolute pressure, in full-face type, from atmosphere (14.7 lb.) down to fractions of one pound. None of *these* pressures register on a common pressure gauge. They correspond to the temperature and heat units, in the same line, of other columns, and also measure the absolute pressure corresponding to the heights of mercury column responding under partial vacuum as given opposite, in full-face type, in inches of height, in column 2. Light face figures in column 1 begin with gauge pressure 3-tenths lb. above atmosphere, corresponding to 15 lb. absolute pressure. The gauge pressures were substituted as being most convenient to use and may generally be read as even pounds, although the 3-tenths are appended to make the pressure agree with the given properties of the steam and liquid originally calculated throughout to correspond with absolute pressure. For absolute pressure above atmosphere, add to the given gauge pressures, 14.7 lb.

The mercury column heights under vacuum, in full-face in column 2 are explained above. The mercury heights in inches for pressure, in light-face, in column 2, corresponding to gauge pressures of column 1, are useful in testing pipe systems, especially gas piping,—mercury gauges being much more reliable than ordinary spring gauges. For heights of columns corresponding with even pounds deduct 0.61 from the heights given,—2.04 inches height of column may be considered as

equaling 1 lb. pressure; with 0.204 as 0.1 lb., $0.204 \times 3 = 0.612$ in., $= \frac{3}{10}$ lb.

Column 3 serves two purposes in this table: It stands as the temperatures corresponding to the pressures of the first column; is normal to the latent heat given in the fourth, and answers for the number of heat units contained in the liquid per pound at the temperatures given, up to 20.3 lbs. gauge. The number of B.t.u. per lb. is a little in excess of the number of F. deg. of the corresponding temperature. This excess grows from nothing at zero to 1.66 B.t.u. at 20.3 lb. gauge, the heat units contained per lb. at 20.3 G.P. being 260.83, while the temperature in F. deg. is 259.17. The common range of work is figured unit for degree, so this discrepancy will make no material difference in estimating surface. The heat of the liquid, (water)—to be taken throughout to be the same for water heating as for water under its corresponding steam temperature—is continued in column 7, while the corresponding temperature are given in column 6, and the pressures in column 5. To find the number of B.t.u. required to raise 1 lb. water from one temperature to another, subtract the units of the lower temperature from those of the higher, as: from 40 deg. to 262.45 takes 222.45; from 50 to 222.37, 172.37; and from 40 to 90 deg. F. requires 50 B.t.u. per lb.

Latent heat as given in the table in the fourth and eighth columns, is the number of B.t.u. absorbed per pound of water vapor or steam generated. It amounts to about 30 times as much per lb. at atmospheric pressure, as is needed to bring a pound of water from 32 deg. F. to boiling point in an open kettle. A thermometer in the liquid takes no notice of this heat; it will raise only until the temperature corresponding to the pressure is reached. As may be inferred from the table, the pressure governs the boiling point,—taken as 212 deg. in the open air (14.7 lb. absolute), 222.37 at 3.3 lb. G.P., 337.81 deg. at 100.3 lb. G.P. and so on. When a pound of steam is condensed in a coil or radiator, it gives up its latent heat to the surrounding water or air, according to the purpose of the surface. The number of B.t.u. made sensible correspond to the temperature and pressure of the steam; this, a definite amount of heat to count on when proportioning coils is shown by the tables. The number of units required per pound of water in any case is equally as definite for any given rise and is as easily found, in the way already described.

CHAPTER V

Circumferences, Areas and Decimal Equivalents of Diameters

Areas and circumferences, of small diameters in decimal, and decimal equivalents of common fractions from $\frac{1}{64}$ to 1, advancing by 64ths, are very useful on many occasions, and the time of need is usually not the most convenient one to work them out. Table III herewith gives such as will be most called for, up to 3 in. diameter. Circumference and area of washers, discs, waterways in valves, etc. are most frequently needed in connection with differential areas, leverage and buoyancy, weight, pressure, etc.

In general, work in decimals is much more satisfactory than in common fractions, and it may be well for some to refresh their memory, even on elementary questions relating to decimals, not only for the work above indicated, but also for the many other applications that familiarity provides the chance to make. A decimal fraction leaves its denominator, 10 or some multiple of 10, to be understood. The decimal point at its left fixes its value, and the first figure, next the point, is tenths; the second, hundredths; etc., as $0.5=\frac{5}{10}$; $0.007=\frac{7}{1000}$,—the denominator *always* being 1, plus as many ciphers as there are figures in the decimal. Ciphers annexed at the right do not change the value. Moving the point in any decimal, one, two, or three places to the right, multiplies the decimal by ten, one-hundred or one-thousand; moving the point to the left, one, two or three places, divides the decimal by ten, one-hundred or one-thousand; moving it 6 places to the right, in the case of 0.5 would therefore change the value to 500000. A pure decimal has no integer figures; a mixed decimal has integers in addition to the decimal figures, as 52.25; a complex decimal expresses two remote places by common fraction, as $.99\frac{44}{100}$, $.5\frac{3}{4}$, etc. Terminate decimals are those in which the division is complete; interminate are those of which the division cannot be completed. Decimals have other names, too, according to characteristics, but need not be considered here.

To change a decimal to a common fraction, add the denominator in common fraction form, as above mentioned, thus: $0.25=\frac{25}{100}$.

To change a common fraction to a decimal, annex as many ciphers to the numerator as required and divide by the denominator; then point off from right to left, as many places in the quotient as there were *used cyphers* in the division. In this way $\frac{19}{64}$ are seen to equal $19.000000 \div 64 = 0.296875$, as given in Table III.

Addition of decimals is the same as common addition; placing similar denominations under each other brings all the decimal points

Table III. Diameters Advancing by 64ths to 1 in.; by 32nds, 1 in. to 2 in., and by 16ths, 2 in. to 3 in., with Decimal Equivalents by 64ths to 1 in. and Circumference and Area, $\frac{1}{64}$ to 3 in.

Fr. diam.	$\frac{1}{64}$	$\frac{1}{32}$	$\frac{3}{64}$	$\frac{1}{16}$	$\frac{5}{64}$	$\frac{3}{32}$	$\frac{7}{64}$	$\frac{1}{8}$
Decimal equivalent......	.015625	.031250	.046875	.062500	.078125	.093750	.109375	.125000
Circumference..........	.049090	.098180	.147260	.196350	.245440	.294520	.343610	.392700
Area..................	.000192	.000767	.001726	.003068	.004794	.006903	.009396	.012272
Fr. diam.	$\frac{9}{64}$	$\frac{5}{32}$	$\frac{11}{64}$	$\frac{3}{16}$	$\frac{13}{64}$	$\frac{7}{32}$	$\frac{15}{64}$	$\frac{1}{4}$
Decimal equivalent......	.140625	.156250	.171875	.187500	.203125	.218750	.234375	.250000
Circumference..........	.441790	.490800	.530960	.589050	.638140	.687220	.736310	.785400
Area..................	.015532	.019175	.023202	.027612	.032405	.037583	.043143	.049087
Fr. diam.	$\frac{17}{64}$	$\frac{9}{32}$	$\frac{19}{64}$	$\frac{5}{16}$	$\frac{21}{64}$	$\frac{11}{32}$	$\frac{23}{64}$	$\frac{3}{8}$
Decimal equivalent......	.265625	.281250	.296875	.312500	.328125	.343750	.259375	.375000
Circumference..........	.834490	.883570	.932660	.981750	1.030840	1.079920	1.129010	1.178160
Area..................	.055415	.062126	.069221	.076699	.084561	.092806	.101435	.110447
Fr. diam.	$\frac{25}{64}$	$\frac{13}{32}$	$\frac{27}{64}$	$\frac{7}{16}$	$\frac{29}{64}$	$\frac{15}{32}$	$\frac{31}{64}$	$\frac{1}{2}$
Decimal equivalent......	.390625	.406250	.421875	.437500	.453125	.468750	.484375	.500000
Circumference..........	1.227190	1.276270	1.325360	1.374450	1.423540	1.472620	1.521710	1.570800
Area..................	.119843	.129622	.139784	.150330	.161260	.172573	.184270	.196350
Fr. diam.	$\frac{33}{64}$	$\frac{17}{32}$	$\frac{35}{64}$	$\frac{9}{16}$	$\frac{37}{64}$	$\frac{19}{32}$	$\frac{39}{64}$	$\frac{5}{8}$
Decimal equivalent......	.515625	.531250	.546875	.562500	.578125	.593750	.609375	.625000
Circumference..........	1.619890	1.668970	1.718060	1.767150	1.816040	1.865320	1.914410	1.963500
Area..................	.208814	.221661	.234891	.248505	.262503	.276884	.291649	.306797
Fr. diam.	$\frac{41}{64}$	$\frac{21}{32}$	$\frac{43}{64}$	$\frac{11}{16}$	$\frac{45}{64}$	$\frac{23}{32}$	$\frac{47}{64}$	$\frac{3}{4}$
Decimal equivalent......	.640625	.656250	.671875	.687500	.703125	.718750	.734375	.750000
Circumference..........	2.012590	2.061670	2.110760	2.159850	2.208940	2.258020	2.307110	2.356200
Area..................	.322328	.338244	.354542	.371224	.388290	.405739	.423571	.441788
Fr. diam.	$\frac{49}{64}$	$\frac{25}{32}$	$\frac{51}{64}$	$\frac{13}{16}$	$\frac{53}{64}$	$\frac{27}{32}$	$\frac{55}{64}$	$\frac{7}{8}$
Decimal equivalent	.765625	.781250	.796875	.812500	.828125	.843750	.859375	.875000
Circumference..........	2.405290	2.454380	2.503460	2.552550	2.601640	2.650720	2.699810	2.748900
Area..................	.460387	.479370	.498737	.518487	.538620	.559137	.580038	.601322
Fr. diam.	$\frac{57}{64}$	$\frac{29}{32}$	$\frac{59}{64}$	$\frac{15}{16}$	$\frac{61}{64}$	$\frac{31}{32}$	$\frac{63}{64}$	1
Decimal equivalent. ..	.890625	.906250	.921875	.937500	.953125	.968750	.984375	1.000000
Circumference..........	2.797990	2.847070	2.896160	2.945250	2.994340	3.043420	3.092510	3.141600
Area..................	.622989	.645040	.667475	.690293	.713494	.737079	.761048	.785400
Diameter	1	$1\frac{1}{32}$	$1\frac{1}{16}$	$1\frac{3}{32}$	$1\frac{1}{8}$	$1\frac{5}{32}$	$1\frac{3}{16}$	$1\frac{7}{32}$
Circumference..........	3.141600	3.239770	3.337950	3.436125	3.534300	3.632470	3.730650	3.828820
Area..................	.785400	.835254	.886643	.930565	.994022	1.050012	1.107537	1.166595
Diameter	$1\frac{1}{4}$	$1\frac{9}{32}$	$1\frac{5}{16}$	$1\frac{11}{32}$	$1\frac{3}{8}$	$1\frac{13}{32}$	$1\frac{7}{16}$	$1\frac{15}{32}$
Circumference..........	3.927000	4.025170	4.123350	4.221520	4.319700	4.417870	4.516050	4.614220
Area..................	1.227187	1.289314	1.352974	1.418169	1.484897	1.553160	1.622955	1.694286
Diameter	$1\frac{1}{2}$	$1\frac{17}{32}$	$1\frac{9}{16}$	$1\frac{19}{32}$	$1\frac{5}{8}$	$1\frac{21}{32}$	$1\frac{11}{16}$	$1\frac{23}{32}$
Circumference..........	4.712400	4.810570	4.908750	5.006920	5.105100	5.203270	5.301450	5.399620
Area..................	1.767150	1.841548	1.917480	1.994947	2.073947	2.154481	2.236549	2.320151
Diameter	$1\frac{3}{4}$	$1\frac{25}{32}$	$1\frac{13}{16}$	$1\frac{27}{32}$	$1\frac{7}{8}$	$1\frac{29}{32}$	$1\frac{15}{16}$	$1\frac{31}{32}$
Circumference..........	5.497800	5.595970	5.694150	5.792320	5.890500	5.988670	6.086850	6.185020
Area..................	2.405287	2.491958	2.580162	2.669900	2.761172	2.853978	2.948318	3.044192
Diameter	2	$2\frac{1}{16}$	$2\frac{1}{8}$	$2\frac{3}{16}$	$2\frac{1}{4}$	$2\frac{5}{16}$	$2\frac{3}{8}$	$2\frac{7}{16}$
Circumference..........	6.283200	6.479550	6.675900	6.872250	7.068600	7.264950	7.461300	7.657650
Area..................	3.141600	3.341018	3.546572	3.758262	3.976087	4.200049	4.430147	4.666380
Diameter	$2\frac{1}{2}$	$2\frac{9}{16}$	$2\frac{5}{8}$	$2\frac{11}{16}$	$2\frac{3}{4}$	$2\frac{13}{16}$	$2\frac{7}{8}$	$2\frac{15}{16}$
Circumference..........	7.854000	8.050350	8.246700	8.443050	8.639400	8.835750	9.032100	9.228450
Area..................	4.908750	5.157255	5.411897	5.672674	5.939587	6.212637	6.491822	6.777143

in vertical alignment; after addition, point off, from the left, in the sum, as many figures as there are decimal figures in the partial sum having the most or as many decimal figures as any of the other numbers added,—in other words, the number containing the most decimal figures amongst the numbers to be added determines the number of decimal places in the sum, as both must have the same number of decimal figures.

For subtraction of decimals, the subtrahend and minuend are written, and the remainder pointed off after subtraction, as in addition.

For multiplication, where the number is to be increased by any multiple of ten, either supply or move the point to the right accordingly, as before indicated; thus $19.375 = .019375 \times 1000$, or $19{,}375 \times 100 = 1{,}937{,}500$; if there are decimal figures in either or both the multiplicand and multiplier, proceed as in ordinary multiplication and then point off, from the right, in the product, as many figures as there are decimal figures in the multiplier and multiplicand combined, as $.8862 \times 1.25 = 1.007810$. If there are not enough figures in the product to do this, as will sometimes be the case, annex cyphers at the left of the product until the point can be located the required number of places from the right, as, $0.25 \times 0.25 = .0625$, or, $.062 \times .031 = .001922$.

Division of decimals, aside from the pointing off, is the same as common division of whole numbers. Cyphers may have to be annexed at the right of the dividend in order to be able to divide at all, or, for the purpose of expressing the remainder or fractional quotient decimally. Point off from the right of the quotient, as many figures as the decimal places of the dividend exceed the decimal places of the divisor, as, $10.33461 \div 0.033 = 313.17$, or, $.068598 \div .666 = .103$, or $.62502 \div .033 = 18.94$, or, $0.75 \div 150 = 0.005$. The latter quotient requires the addition of two cyphers at the left of the digit, 5, because one cypher was necessary at the right of the dividend to make division possible, and the decimal places of the dividend then exceed those of the divisor by 3 places,—$.005 = \frac{5}{1000}$; $\frac{5}{1000} \times 150 = \frac{750}{1000}$,—$= 0.75$. In speaking of pointing off figures, cyphers are counted as figures,—it is *places* that count in locating a decimal point, regardless of whether they be cyphers or digits. Remote decimal figures are dropped for ordinary work, and *must* be dropped, at some point, in the case of interminates. Those which represent $\frac{1}{3}$ and $\frac{2}{3}$, are examples of circulating decimals which continue to repeat the *same* figures; others repeat the same *set* of figures.

In table III, decimal equivalents of the diameters greater than 1.0 are not given, but may be derived, as directed, by changing the fractional part to a decimal (or selecting it from the given fractions) and adding it to the integers, as $1\frac{21}{32} = 1.65625$; $2\frac{13}{16} = 2.8125$. The whole diameter (mixed decimal) may also be resolved into a vulgar fraction and proceeded with as directed, thus: $1\frac{21}{32} = \frac{53}{32}$; $\frac{53}{32} = 53.00000 \div 32 = 1.65625$.

When finding what per cent. one number is of another, the larger number is usually, though either may be, according to purpose, considered the *base*, the lesser, the *percentage* and the quotient arising from dividing one by the other as the *rate* or per cent. If it is desired to know what per cent. of 1.42 is .654: *percentage* divided by the *base* equals the *rate*, thus: .654 (percentage) $\div$ 1.42 (base) = .460, the *rate*, or the per cent. that .654 is of 1.42; if the per cent. 1.42 is of .654 is wanted,—1.42 $\div$ .654 = 2.171, 2.171^{+} times .654 being 1.42; or, 2.171^{+} expressed as per cent., 1.42 taken as the *percentage*, is, 217.1 per cent of .654. This looks confusing until it is remembered that one per cent. is $\frac{1}{100}$ and that *any* quantity is 100 per cent. of itself; 2.17^{+} *times* .654 is then seen to be 217.1 times *one per cent.*, or 217.1 per cent. 217.1 is $\frac{217}{100}$ and resulted from applying the common rule:—

"Divide the number considered the *percentage* by *one per cent.* of the other number." The quotient rate .46 in the first example above would be by this rule: 46., 46 per cent.,—$\frac{46}{100}$, or as above expressed, .46 per cent. of 1.42. *Base* multiplied by the *rate* equals the *percentage*, thus, using the same figures as before, 1.42 $\times$ .46 = .654, the percentage. *Percentage* divided by the *rate* equals the *base*, thus, .654 $\div$ .46 = 1.42, the *base*. *Base*, plus *percentage*, divided by 1 plus the *rate*, equals the *base*, thus: 1.42 + .654 = 2.074; 2.074 $\div$ 1.46 = 1.42, the *base*. *Base* minus *percentage*, divided by 1 minus the *rate* equals the *base*, thus: 1.42 —.654 = .766; 1.0—.46 = .54; .766 $\div$ .54 = 1.4185+, within $\frac{15}{10000}$ of 1.42, the *base*,—the shortage being due to remote decimals not represented.

The latter two propositions mean merely the finding of *what number plus* or minus a certain per cent. of *itself* will equal a given *number*, as, 150 is some number minus 20 per cent., what is the number? 1.0—0.20 = 0.80; 150 $\div$ 0.80 = 187.5, the required number, or, as, 187.5 is some number plus 25 per cent., what is the number? 1.0 + .25 = 1.25; 187.5 $\div$ 1.25 = 150. To put one of these cases in other words: Some work or goods cost $9.50, it is desired to make 25 per cent. on the selling or charging price,—at what price should the charge be entered? 1.0—0.25 = .75; 9.50 $\div$ .75 = $12.66, the selling price. In practice, with this particular rate of profit, merely adding $33\frac{1}{3}$ per cent. of the cost to the cost answers, as the cost plus $\frac{1}{3}$ is always equal to 25 per cent. on the selling price.

If a fixture is made or purchased at a cost of $56.00 and it is desired to make 40 per cent. total profit on the cost and to sell at 30 per cent. discount from a list price to be established, what should the list price be? 56. $\times$ .40 = $22.40, 40 per cent. of $56.00; 56.00 + 22.40 = $78.40, the cost plus the profit,—56. $\times$ 1.40 produces the same result. Now, to raise 78.40 to a price providing for 30 per cent. discount that will leave 40 per cent. profit on the cost:—1.0—.30 = .70; 78.40 $\div$ .70 = $112.00,

the list price. $112.00 ÷ $56.00 = 2; 2 is therefore a direct multiplier for use on the cost to produce the list for any article of whatever cost, so long as the profit required is .40 per cent. on the cost and the discount to be given from the list is 30 per cent., as: an article cost $20.00; 20. × 2. = $40.; 40. less 30 per cent. = 28.; 28.—20., the cost, = $8.00 profit; 8.00 ÷ 20.00 = .40 per cent. profit on the cost. Again, let the fixture cost $40.00, the profit required 30 per cent. and the discount to be given from list 20 per cent.: 40. + 30 per cent. = 52.; 52. ÷ .80 = 65.00 the list price, as proved by,—65. less 20 per cent. = 52.; 52.—40 = 12.00; 12. ÷ 40. = .30, the per cent. profit required; the list price, $65.00 divided by the cost price equals 1.625, a multiplier for raising any cost, to the proper list price, where 30 per cent. profit and 20 per cent. discount from the list are the selling conditions. Suppose market conditions suggest shading the regular price, and the article, costing the same, is sold at 20 and 10 per cent. discount; what figure does this extra 10 per cent. concession cut with the profit on the last mentioned cost? $65.00 less 20 per cent. equals 80 per cent. of $65.00; therefore, 65. × .80 = $52.00, the selling price at *20* per cent. off. With the extra 10 per cent. off, .90 per cent. of $52.00 will be received for the article,—supplementary trade discounts being always figured from the net, which all told is, in this case, 20 per cent. off of the amount and then 10 per cent. off of the remainder,—20 and 10 from 1. being *.72* instead of the straight 30 per cent. which from 1. would leave *.70*; then, 52.00 × .90 = $46.80, the selling price at 20 and 10 off; 46.80—40.00 = 6.80; 6.80 ÷ 40.00 = .17 per cent. profit,—showing a difference of 13 per cent. in the profit on the cost as the result of selling the article at *20 and 10* per cent. instead of 20 per cent.

The rules for percentage reduced to formulae are:

Case I;—$\mathbf{b} \times \mathbf{r} = \mathbf{p}$; Case II;—$\mathbf{p} \div \mathbf{b} = \mathbf{r}$; Case III;—$\mathbf{p} \div \mathbf{r} = \mathbf{b}$,

and, Case IV;—$\mathbf{b} \times (\mathbf{1} + \mathbf{r}) = \mathbf{a}$; Case V;—$\mathbf{b} \times (\mathbf{1} - \mathbf{r}) = \mathbf{R}$, in which **a** is the amount, **b** the base, **r** the rate, **p** the percentage, and **R** the remainder.

Supplementary trade discounts to the number of 6 or more are given at times, usually in the shape of 10's off of a base discount, as 40, 10-10-10- and 10: or, 40, 10-10-10 and 5, etc. These perspectives in discounts are rare, however. Less rarer combinations especially in the hardware line are: 20-10-7½-5, equaling .6327 per cent., net, straight discount; 20-10-7½ = .666, net; 20-10-5-2½ = .6669, net; 20-10-5 = .684, net; 20-10 = .72, net; 20-5-2½ = .741, net, and 20-5, equaling .76, net. The base, 20, used here is merely for a comparison of the combination discounts,—it may be more or less in practice. It may be said that it is impossible to wipe out the *net* by any number or combination of discounts from the net, no matter how large they may be. This is obvious when it is

noted that 90 and *ten 10's* discount, figured off of 1. in the ordinary way, leave .03486784401, about $3\frac{1}{2}$ per cent.

United States money denominations are based on the decimal system and in it, we take ten of one denomination as making one of the next higher, indefinitely, while it is English practice to terminate the denominations of ten at millions and substitute the square of a million for a billion.

Interest on loans is expressed decimally, and while occasional application of some of the many rules may confuse one, simple interest problems are not difficult if the fundamental principle is borne in mind. Any rate per cent. per annum, is just so many $\frac{1}{100}$ of the principal per year. The interest for one day is $\frac{1}{360}$ or $\frac{1}{365}$ of the year's interest according to the rule used, which, by the days in the period equals the interest; the year's interest is one (.01) per cent. of the principal, at one per cent. interest, and one per cent. multiplied by the rate per cent. for any other rate.

The interest on $1.00 at 6 per cent. is, for one day, .0001644; for one month (ordinarily taken as 30 days), .004932; for one year, .06,—from this arises the 360-day year rule of taking, as a direct multiplier, the sum of 6 *hundredths* for each year, *half* as many *hundredths* as there are odd months, and *one-sixth* as many *thousandths* as there are odd days in the time. The principal multiplied by the decimal so derived gives the interest for the period, based on 360 days to the year and 30 days each for the months; thus for $1.00 at 6 per cent. for one year, 6 months and 18 days, the multiplier is footed up from .06 (for the year) .03 (for the month) .003 (for the days) $=.093$; $1.00\times.093=.093$ (the interest); $.093+1.00=\$1.093$, the *interest and principal.*

For $100.00 at the same rate and time, the interest would be $9.30, and the interest and principal, $109.30. Of course, instead of finding the interest separately with the multiplier and then adding it to the principal, the interest decimal, .093, can be changed to 1.093 so as to produce the interest and principal in the product of one operation.

Taking the time stated as $565\frac{1}{2}$ days and using the one-day-interest-at 6 per cent. decimal .0001644 (stated above) the interest on $100.00 figures to be $9.29682,—the interest for one day on 1.00 being .0001644, $.0001644\times100=.01644$, interest on $100.00 for one day; $.01644\times365=6.0006$, interest for one year, and as above given, for one year, 6 months, 18 days, taken as $565\frac{1}{2}$ days, equals $9.29682.

The rule as stated for a 360-day year and 30 days taken as a month is easy applied and accurate enough for ordinary purposes. Compound interest is interest computed on and added to the principal at intervals of less than a year, quarterly or semi-annually, and is, in effect, merely a higher rate than expressed by the annual rate on which it is computed.

Having the interest at six per cent., any other rate is in proportion. For 8 per cent. per annum the interest is 6 per cent. interest plus $\frac{1}{3}$ of

6 per cent. interest; for $7\frac{1}{2}$ per cent., 6 per cent. plus $\frac{1}{4}$ of 6 per cent. interest; for 7 per cent., 6 per cent. plus $\frac{1}{6}$; for 5 per cent., $\frac{5}{6}$ of 6 per cent.; for 4, $\frac{2}{3}$; for 3, $\frac{1}{2}$; for 2, $\frac{1}{3}$ and for 1 per cent., $\frac{1}{6}$ of the interest at 6 per cent. per annum.

The French Metric System, long since made semi-official by an act of Congress and coming more and more into use in this country, is expressed decimally. In fact, so generally are Metric measures specified, in lieu of feet and inches, pounds and ounces, etc., as to make it worth the while to here give the following Metric expressions and their English equivalents:

Table IV. English Weight and Measure Equivalents of Metric Quantities

	Pounds and Ounces		
1-kilogram	= 2.679 lb. Troy	; 1-lb. Troy	= 0.3732 kilogrammes
1-gramme	= 0.032 oz. Troy	; 1-oz. Troy	= 31.1035 grammes
1-gramme	= 15.432 gr. Troy	; 1-gr. Troy	= 0.0648 grammes
1-kilogramme	= 2.204 lb. Av.	; 1-lb. Av.	= 0.4536 kilogrammes
1-gram	= 0.035 oz. Av.	; 1-oz. Av.	= 28.35 grammes
	Liquid and Dry Measure		
1-dekaliter	= 2.6417 gals.	; 1 gal.	= 0.3785 dekaliter
1-liter	= 1.0567 liq. qts.	; 1 liq. qt.	= 0.9463 liter
	Cubic Measure		
1-cu. meter	= 1.308 cu. yds.	; 1-cu. yd.	= 0.7645 cu. meter
1-cu. decimeter	= 0.035 cu. ft.	; 1-cu. ft.	= 28.317 cu decimeters
1-cu. centimeter	= 0.061 cu. in.	; 1-cu. in.	= 16.387 cu.centimeters
	Square Measure		
1-sq. meter	= 1.196 sq. yds.	; 1-sq. yd.	= 0.836 sq. meter
1-sq. decimeter	= 0.1076 sq. ft.	; 1-sq. ft.	= 9.290 sq. decimeter
1-sq. centimeter	= 0.1550 sq. in.	; 1-sq. in.	= 6.452 sq. centimeters
	Measures of Length		
1-kilometer	= 0.62137 mile	; 1-mile	= 1.6093 kilometers
1-meter	= 1.0936 yds.	; 1-yd.	= 0.9144 meter
1-decimeter	= 0.328 ft.	; 1-ft.	= 3.048 decimeters
1-centimeter	= 0.3937 in.	; 1-in.	= 2.540 centimeters

One meter equals 39.37 English inches

The Tables of English weights and measures likely to be needed with the above, are:—

Avoirdupois Weight

1-lb. =16 ozs. or 7000 gr.
1-oz. =16 drachms or $437\frac{1}{2}$ gr.
1-drachm $=27\frac{11}{32}$ gr.

Troy Weight

1 lb. =12 ozs. or 5760 gr.
1-oz. =20 pennyweight, or 480 gr.
1-pennyweight =24 gr.

Troy Equivalents of Avoirdupois Weight

1-lb. Avoirdupois	= 1.215278 Troy lb.	; 1-Avoirdupois oz.	= 0.911458 Troy oz.
1-lb. Avoirdupois	= 14.583333 Troy ozs.	; 1-Avoirdupois oz.	= 18.22916 pennyweight

U. S. Liquid Measure

		Approximate	
1-gal.	= 4 qts.	=231 cu. in.	=8.3 lb. water
1-qt.	= 2 pts.	= 57.75 cu. in.	=2.075 lb. water
1-pt.	= 4 gills	= 28.87 cu. in.	=1.037 lb. water
1-gill	= 4 U. S. fl. oz.	= 7.22 cu. in.	=0.260 lb. water
1-fl. oz.*	= 8 fl. dr.	= 1.8 cu. in.	=0.065 lb. water
1-fl. dr.	=60 minims	= 0.00376 cu. in.	=0.95 gr.

* 1-fl. oz. =480 minims.

Dry Measure

1-gal. = 268.8 cu. in.
1-qt. = 67.2 cu. in.
1-pt. = 33.6 cu. in.

Long Measure

1-mile =1760 yds. =5280 ft.
1-yd. =3 ft.
1-ft. =12 in.

Cubic Measure

1 cu. yd. =27 cu. ft.
1-cu. ft. =1728 cu. in.

Square Measure

1-sq. yd. =9 sq. ft.
1-sq. ft. =144 sq. in.
1-sq. mile =640 acres; 1 acre =208.71 ft. sq. =4840 sq. yds. =43560 sq. ft.

Table IV—Cont'd

The *meter* is the unit of measures of length in the metric system. The *liter* is the unit of dry and liquid measure,—its dimensions are equal to $\frac{1}{10}$ of a meter on a side—a decimeter, cubed. The *gram* is the unit of weight. A gram is one cubic centimeter,— $\frac{1}{1000}$ of a liter of pure water measures at 39.2 deg. F. in vacuum. A cubic centimeter is a cube with dimensions of $\frac{1}{100}$ of a meter on a side.

The subordinate units are named by prefixing to the standard units: for multiples of the units, the Greek numerals, *kilo-* for 1000; *hecto-* for 100, and *deka-* for 10,—as, *kilo*-meter, *hekto*-liter and *deka*-gram. For subdivisions of the units, the Latin numerals are used, prefixing *deci-* for $\frac{1}{10}$; *centi-* for $\frac{1}{100}$, and *milli-* for $\frac{1}{1000}$,—as *deci*-liter; *centi*-gram, and *milli*-meter.

Table V. Metric Measures of Length

1-millimeter =0.001 meter
1-centimeter =0.01 meter
1-decimeter =0.1 meter

Fractions of the meter

10-millimeters =1-centimeter
10-centimeters =1 decimeter
10-decimeters =1 meter

Multiples of the Meter

10-meters =1 dekameter
10-dekameters =1 hektometer
10-hektometers =1 kilometer

To approximately convert:

Price per meter to price per yard,—deduct 10 per cent.
Meters to feet,—add 10 per cent. and multiply by 3.
Meters to inches,—add 10 per cent. and multiply by 36.
Liters to liquid quarts,—add 6 per cent.
Cubic centimeters to U. S. fl. dr.,—divide by 44.
Cubic centimeters to fl. oz.,—divide by 30.
Grams to Avoirdupois oz.,—divide by 30 and add 6 per cent.
Kilograms to Avoirdupois lbs.,—multiply by 2 and add 10 per cent.
Price per Avoirdupois lb. to price per kilogram,—divide by 2.2.

For those who have occasion to use Vernier readings with any of the foregoing measures of length, the following table of decimal equivalents of fractions of a millimeter will be of service:

Table VI. Equivalents of Hundredths of Millimeters in Decimals of an Inch

Hundredths of Millimeters	0	1	2	3	4	5	6	7	8	9
1– 9	......	.00039	.00079	.00118	.00157	.00197	.00236	.00275	.00315	.00354
10–19	.00394	.00433	.00472	.00512	.00551	.00590	.00630	.00669	.00709	.00748
20–29	.00787	.00826	.00866	.00905	.00945	.00984	.01024	.01063	.01102	.01141
30–39	.01181	.01220	.01260	.01299	.01339	.01378	.01417	.01456	.01496	.01535
40–49	.01575	.01614	.01654	.01693	.01732	.01771	.01811	.01850	.01890	.01929
50–59	.01969	.02008	.02047	.02086	.02126	.02165	.02205	.02244	.02283	.02322
60–69	.02362	.02401	.02441	.02480	.02520	.02559	.02598	.02637	.02677	.02716
70–79	.02756	.02795	.02835	.02874	.02913	.02952	.02992	.03031	.03071	.03110
80–89	.03150	.03189	.03228	.03267	.03307	.03346	.03386	.03425	.03465	.03504
90–99	.03543	.03582	.03622	.03661	.03701	.03740	.03780	.03819	.03858	.03897

Note—The equivalent fractions of an inch are found in the body of the table,—10, 20, 30 hundredths, etc., in the first column under 0, and the tens plus the units at the intersections, as: Tracing horizontal to the right from 60 to under 2 at the head of the table finds .02441 which is $\frac{62}{100}$ of a millimeter expressed decimally in inches.

$\frac{1}{100}$ millimeter = 0.0003937 inch
1 millimeter = 0.03937 inch
1 centimeter = 0.3937 inch
1 decimeter = 3.937 inch
1 meter =39.37 inch
25.4 millimeters = 0.999998 inch, and are taken to equal 1 English inch.

CHAPTER VI

Squares, Cubes, Roots, Etc.

Table VII gives what are generally designated as numerical constants, including the sides of squares of equal area and the reciprocals of numbers from one to one hundred. The functions given are usually divided into several tables, making it very inconvenient to refer to the various properties of a number. In the lower box of the head, over each column, is given the common name of the term. In the upper boxes of the head, over corresponding columns are given the designations or formula often found heading these functions in the tables of engineering books. The latter mentioned headings are given as an aid to quick recognition of any term or process so indicated that may be encountered elsewhere by those whose experience have been mostly with the common English terms.

n, over the first column represents the number. The number may be taken as feet, inches, yards, meters, etc. and the result of any operation will be like terms. $\mathbf{n}\pi$ given at the right in second column head stands for ratio of circumference to diameter,—3.1416 to 1. Any diameter multiplied by 3.1416 equals the circumference,—$\mathbf{n}\times\pi$ = circumference is what is meant by $\mathbf{n}\pi$ in second column head; it is not unusual to omit the multiplication sign, and when symbols are printed beside each other as $\mathbf{n}\pi$, multiplication of one by the other is intended and understood.

In the third column is given the area of circles, the finding of which being usually expressed as "the square of the diameter multiplied by .7854 = area". The upper box of the third column head expresses the same thing,—meaning that the second power of the number is to be multiplied by $\frac{1}{4}$ *pi* to obtain the area. A number is in itself a power,—the first power of itself; multiplying the number by itself, *squares* it,—that is, raises it to its second power. The power is indicated by setting the exponent superior to the number or its symbols, as shown in columns of the table head. Raising a number to higher powers is called involution. Pi, 3.1416, the ratio of circumference to diameter, divided by 4, equals .7854, or $\frac{1}{4}$ *pi*, or $\frac{1}{4}\,\mathbf{n}\pi$. Thus for the area of any circle, apply the common rule above given, as, $4\times4=16$; $16\times.7854=12.566$, the area of a 4-inch circle.

The "Why" will be made more apparent by a later reference to inscribed circles, the area of which, to the circumscribing square with side equal to the circles diameter is always as .7854 is to 1.0

The fourth column gives the numbers of the first, *squared*; that is,

Table VII. Some Functions of the Numbers One to One Hundred

n	$n\pi$	$n^2\frac{\pi}{4}$	n^2	$\sqrt[2]{n}$	n^3	$\sqrt[3]{n}$	n.8862	$\frac{1}{n}$
Number	Circumference	Area	Square	Square Root	Cube	Cube Root	Side of Equal Square	Reciprocal
1	3.142	0.7854	1.0	1.0000	1.0	1.0000	0.8862	.000000
2	6.283	3.1416	4.0	1.4142	8.0	1.2599	1.7724	.500000
3	9.425	7.0686	9.0	1.7321	27.0	1.4422	2.6587	.333333
4	12.566	12.566	16.0	2.0000	64.0	1.5874	3.5449	.250000
5	15.708	19.635	25.0	2.2361	125.0	1.7100	4.4311	.200000
6	18.850	28.274	36.0	2.4495	216.0	1.8171	5.3174	.166667
7	21.991	38.485	49.0	2.6458	343.0	1.9129	6.2036	.142857
8	25.133	50.266	64.0	2.8284	512.0	2.0000	7.0898	.125000
9	28.274	63.617	81.0	3.0000	729.0	2.0801	7.976	.111111
10	31.416	78.540	100.0	3.1623	1000.0	2.1544	8.8623	.100000
11	34.558	95.033	121.0	3.3166	1331.0	2.2240	9.7485	.090904
12	37.699	113.10	144.0	3.4641	1728.0	2.2894	10.6347	.083333
13	40.841	132.73	169.0	3.6056	2197.0	2.3513	11.5209	.076923
14	43.982	153.94	196.0	3.7417	2744.0	2.4101	12.4072	.071429
15	47.124	176.72	225.0	3.8730	3375.0	2.4662	13.2934	.066667
16	50.265	201.06	256.0	4.0000	4096.0	2.5198	14.1796	.062500
17	53.407	226.98	289.0	4.1231	4913.0	2.5713	15.0659	.058824
18	56.549	254.47	324.0	4.2426	5832.0	2.6207	15.9521	.055556
19	59.690	283.53	361.0	4.3589	6859.0	2.6684	16.8383	.052632
20	62.832	314.16	400.0	4.4721	8000.0	2.7144	17.7245	.050000
21	65.973	346.36	441.0	4.5826	9261.0	2.7589	18.6108	.047619
22	69.115	380.13	484.0	4.6904	10648.0	2.8020	19.497	.045455
23	72.257	415.48	529.0	4.7958	12167.0	2.8439	20.3832	.043478
24	75.398	452.39	576.0	4.8990	13824.0	2.8845	21.2694	.041667
25	78.540	490.87	625.0	5.0000	15625.0	2.9240	22.1557	.040000
26	81.681	530.93	676.0	5.0990	17576.0	2.9625	23.0419	.038462
27	84.823	572.56	729.0	5.1962	19683.0	3.0000	23.9281	.037037
28	87.965	615.75	784.0	5.2915	21952.0	3.0366	24.8144	.035714
29	91.106	660.52	841.0	5.3852	24389.0	3.0723	25.7006	.034483
30	94.248	706.86	900.0	5.4772	27000.0	3.1072	26.5868	.033333
31	97.389	754.77	961.0	5.5678	29791.0	3.1414	27.473	.032258
32	100.53	804.25	1024.0	5.6569	32768.0	3.1748	28.3593	.031250
33	103.67	855.30	1089.0	5.7446	35937.0	3.2075	29.2455	.030303
34	106.81	907.92	1156.0	5.8310	39304.0	3.2396	30.1317	.029412
35	109.96	962.11	1225.0	5.9161	42875.0	3.2111	31.0179	.028571
36	113.10	1017.88	1296.0	6.0000	46560.0	3.3019	31.9042	.027778
37	116.24	1075.21	1369.0	6.0828	50653.0	3.3322	32.7904	.027027
38	119.38	1134.11	1444.0	6.1644	54872.0	3.3620	33.6766	.026316
39	122.52	1194.59	1521.0	6.2450	59319.0	3.3912	34.5628	.025641
40	125.66	1256.64	1600.0	6.3246	64000.0	3.4200	35.4491	.025000
41	128.81	1320.25	1681.0	6.4031	68921.0	3.4482	36.3353	.024390
42	131.95	1385.44	1764.0	6.4807	74088.0	3.4760	37.2215	.023810
43	135.09	1452.20	1849.0	6.5574	79507.0	3.5034	38.1078	.023256
44	138.23	1520.53	1936.0	6.6332	85184.0	3.5303	38.994	.022727
45	141.37	1590.43	2025.0	6.7082	91125.0	3.5569	39.8802	.022222
46	144.51	1661.90	2116.0	6.7823	97336.0	3.5830	40.7664	.021739
47	147.65	1734.94	2209.0	6.8557	103823.0	3.6088	41.6527	.021277
48	150.80	1809.56	2304.0	6.9282	110592.0	3.6342	42.539	.020833
49	153.94	1885.74	2401.0	7.0000	117649.0	3.6593	43.4251	.020408
50	157.08	1963.50	2500.0	7.0711	125000.0	3.6840	44.3113	.020000

Table VII Cont'd. Some Functions of the Numbers One to One Hundred

n Number	$n\pi$ Circum-ference	$n^2\frac{\pi}{4}$ Area	n^2 Square	$\sqrt[2]{n}$ Square Root	n^3 Cube	$\sqrt[3]{n}$ Cube Root	$n.8862$ Side of Equal Square	$\frac{1}{n}$ Recip-rocal
51	160.22	2042.82	2601.00	7.1414	132651.0	3.7084	45.1976	.019608
52	163.36	2123.72	2704.00	7.2111	140608.0	3.7325	46.0838	.019231
53	166.50	2206.19	2809.00	7.2801	148877.0	3.7563	46.9700	.018868
54	169.64	2290.22	2916.00	7.3485	157464.0	3.7798	47.8562	.018519
55	172.78	2375.83	3025.00	7.4162	166375.0	3.8030	48.7425	.018182
56	175.93	2463.01	3136.00	7.4833	175616.0	3.8259	49.6287	.017857
57	179.07	2551.76	3249.00	7.5498	185193.0	3.8485	50.5149	.017544
58	182.21	2642.08	3364.00	7.6158	195112.0	3.8709	51.4012	.017241
59	185.35	2733.97	3481.00	7.6811	205379.0	3.8930	52.2874	.016949
60	188.49	2827.44	3600.00	7.7460	216000.0	3.9149	53.1736	.016667
61	191.63	2922.47	3721.00	7.8102	226981.0	3.9365	54.0598	.016393
62	194.77	3019.07	3844.00	7.8740	238328.0	3.9579	54.9461	.016129
63	197.92	3117.25	3969.00	7.9373	250047.0	3.9791	55.8323	.015873
64	201.06	3216.99	4096.00	8.0000	262144.0	4.0000	56.7185	.015625
65	204.20	3318.31	4225.00	8.0623	274625.0	4.0207	57.6047	.015385
66	207.34	3421.20	4356.00	8.1240	287496.0	4.0412	58.4910	.015152
67	210.48	3525.66	4489.00	8.1854	300763.0	4.0615	59.3772	.014925
68	213.63	3631.69	4624.00	8.2462	314432.0	4.0817	60.2634	.014706
69	216.77	3739.29	4761.00	8.3066	328509.0	4.1016	61.1497	.014493
70	219.91	3848.46	4900.00	8.3666	343000.0	4.1213	62.0359	.014286
71	223.05	3959.20	5041.00	8.4261	357911.0	4.1408	62.9221	.014085
72	226.19	4071.51	5184.00	8.4853	373248.0	4.1602	63.8083	.013889
73	229.33	4185.39	5329.00	8.5440	389017.0	4.1793	64.6946	.013699
74	232.47	4300.85	5476.00	8.6023	405224.0	4.1983	65.5808	.013514
75	235.62	4417.87	5625.00	8.6603	421875.0	4.2172	66.4670	.013333
76	238.76	4536.47	5776.00	8.7178	438976.0	4.2358	67.3532	.013158
77	241.90	4656.63	5929.00	8.7750	456533.0	4.2543	68.2395	.012987
78	245.04	4778.37	6084.00	8.8318	474552.0	4.2727	69.1257	.012821
79	248.18	4901.68	6241.00	8.8882	493039.0	4.2908	70.0119	.012658
80	251.32	5026.50	6400.00	8.9443	512000.0	4.3089	70.8981	.012500
81	254.47	5153.01	6561.00	9.0000	531441.0	4.3267	71.7844	.012346
82	257.61	5281.03	6724.00	9.0554	551368.0	4.3445	72.6706	.012195
83	260.75	5410.62	6889.00	9.1104	571787.0	4.3621	73.5568	.012048
84	263.89	5541.78	7056.00	9.1652	592704.0	4.3795	74.4431	.011905
85	267.03	5674.50	7225.00	9.2195	614125.0	4.3968	75.3293	.011765
86	270.17	5808.81	7396.00	9.2736	636056.0	4.4140	76.2155	.011628
87	273.32	5944.69	7569.00	9.3274	658503.0	4.4310	77.1017	.011494
88	276.46	6082.13	7744.00	9.3808	681472.0	4.4480	77.9880	.011364
89	279.60	6221.13	7921.00	9.4340	704969.0	4.4647	78.8742	.011236
90	282.74	6361.74	8100.00	9.4868	729000.0	4.4814	79.7604	.011111
91	285.88	6503.89	8281.00	9.5394	753571.0	4.4979	80.6467	.010989
92	289.02	6647.62	8464.00	9.5917	778688.0	4.5144	81.5329	.010870
93	292.17	6792.92	8649.00	9.6437	804357.0	4.5307	82.4191	.010753
94	295.31	6939.78	8836.00	9.6954	830584.0	4.5468	83.3053	.010638
95	298.45	7088.23	9025.00	9.7468	857375.0	4.5629	84.1916	.010526
96	301.59	7238.24	9216.00	9.7980	884736.0	4.5789	85.0778	.010417
97	304.73	7389.83	9409.00	9.8489	912673.0	4.5947	85.9646	.010309
98	307.87	7542.98	9604.00	9.8995	941192.0	4.6104	86.8502	.010204
99	311.02	7697.68	9801.00	9.9499	970299.0	4.6261	87.7364	.010101
100	314.16	7854.00	10000.00	10.0000	1000000.0	4.6416	88.6227	.010000

each multiplied by itself once,—raised to the second power, as $25\times25=625$; $625=25^2$.

The fifth column gives the square roots of the numbers in the first; that is, the numbers in the first column are squares of the roots given in the fifth; put in other words, the roots in the fifth column raised to their second powers produce the numbers of the first column. Likewise, each number in the first column is really the square root of its square given in the fourth column, and the cube root of its cube given in the sixth column. In the upper box of the fifth column is given the radical sign (made much like a capital V) with the index of the root required placed within it; the radical sign *without* and index is universally taken to indicate that the square root if the quantity it appears with it is to be taken. Adding the index, in the case of square root, can only make it absolutely certain that the root of some other power is not wanted and of which the supplying of the index was overlooked,—just as leaving the unit place blank indicates no units, yet filling it with a cypher makes it certain to the reader that some unit was not intended and forgotten, as .91 may have been intended to be 1.91, 9.91 or 3.91, but 0.91 leaves no doubt about the units. The quantity of which the root is to be or was taken, as designated in the fifth column head, is **n**,—the number in the first column. The bar or *vinculum* extending from the radical sign, as in the fifth and seventh columns, covers the quantity of which the root is to be taken; when the root of a sum, product or quotient is to be taken, the bar is extended to cover the quantities and signs. Finding the roots of numbers is called evolution.

In the sixth column the cubes of the numbers of the first are given, as indicated by the symbol and exponent with it. Cubing a number raises it to the third power. Any square multiplied by its root gives the third power of the root,—this is the same as saying any number multiplied, first by itself and then by the product (square or second power) gives the cube or third power of the number, thus: $2\times2=4$, and $2\times4=8$, the cube of 2; or $4\times4\times4=64$, the cube of 4; $64=4^3$.

In the seventh column, the cube root of the numbers of the first column, considered as numbers in their third power, are given; the relation of seventh column numbers to those of the first column is therefore the same as that of the first column numbers to those of the sixth column. Other roots besides those indicated in the column headings are available from the table numbers. The roots given in the seventh column are also the *sixth roots* to the numbers given in the fourth column, and the *ninth roots* of those given in the sixth column; and, the roots given in the fifth column are also the *fourth roots* of the numbers given in the fourth column, and the *sixth roots* of those given in the sixth column. These numbers are, of course, powers corresponding to their roots; that is, 64 in the sixth column is the sixth power of 2, in the fifth

column, etc. It will be noted from the above that the fourth root is obtained by extracting the square root of the square root of the number; the sixth root by extracting the *square root* of the *cube root* or, *cube root* of the *square root*; and, the ninth root by extracting the *cube root* of the *cube root* of the number.

The extraction of roots is best studied from a good common arithmetic where the sole purpose is to present rules and illustrative examples at sufficient length to make plain the principles involved. The following, however, may supplement and will, perhaps, make clearer, in some respects, that which is gleaned from school book rules. In addition to the roots given and indicated, the roots of many decimals may be determined through the aid of the table by proceeding as follows:

There are as many figures in the *square root* of a number as there are periods of *two figures* in the number, and as many figures in the *cube root* of a number as there are periods of *three figures* in the number. Therefore, when a table is at hand, to easily find the square root of a decimal, consider it as being a whole number and find the root from the table; then point off from the right as many places as there are periods of two figures in the decimal, thus: what is the square root of 0.7744? Square root of 7744. is 88.0; there are two periods of two figures each in .7744, so, two figures are to be pointed off in 88.0, thus giving 0.88 as the square root of 0.7744,—$0.88 \times 0.88 = 0.7744$; or, to find the square root of .0064; of 64.0 it equals 8.0; the point moved two places for the two periods in .0064 gives .08 as the square root of .0064,—$.08 \times .08 = .0064$. In the case of half a period being at the right of a decimal when pointed off, as .784, add one cypher to make even periods, for square root, else the result, *found* as *above directed* would, in the case of .784, be 28. as the root of the decimal taken as a whole number, instead of $88\frac{1}{2}^{+}$, the root of 7840. taken as .7840 decimal and read as a whole number. 88.5^{+} ($82\frac{1}{2}$) gives, when the point is moved two places, 0.885 as the square root of 0.784; $0.885 \times 0.885 = 0.783^{+}$. .784 and .7840 as decimals are the same value, but when the root for two periods is to be found, two periods must be used to get the root of a whole number that the rule will apply to. Cube roots of decimals can be found in the same way, except that the point must be moved one place for each period of *three* figures in the decimal.

It should be remembered that the periods pointed off for finding roots of whole numbers must begin at the right of the number, while decimals are pointed off for the same purpose, beginning at the decimal point,—the left. This applies to complex decimals as well as integers and decimals alone, though in practice, it is the same with complex decimals, if the integers only are pointed off right to left and the bringing down of two or three figure periods, as the case requires, continued throughout. The figures of the root derived from the decimal periods,

must, of course, be separated from the balance by a point placed in the root quotient so as to define the decimal portion of the root.

Short cuts in figures are generally tricky unless one is thoroughly familiar with the principles, and should not be applied to business until fully mastered. This applies somewhat to the following:

For the *circumference* of any diameter ten times as great as that of a given diameter, move the decimal point *one* place to the right in the circumference of the lesser diameter, thus: circumference of $\frac{1}{32}$ is 0.098,—of $\frac{5}{16}$ ($\frac{1}{32} \times 10 = \frac{5}{16}$) it is 0.98; circumference of $\frac{1}{16}$ is 0.196,—of $\frac{5}{8}$ ($\frac{1}{16} \times 10 = \frac{5}{8}$) it is 1.96.

For the *area* of any diameter ten times as great as that if a given diameter, move the decimal point *two* places to the right in the area for the lesser diameter, thus: area of $\frac{1}{32}$ is .000767,—of $\frac{5}{16}$ it is 0.0767; area of $\frac{1}{16}$ is .00307,—of $\frac{5}{8}$ it is 0.307; area of 2 is 3.1416,—of 20 it is 314.16.

Any given *square* is 100 times the square of a number one-tenth that of the *root* of the given square. Then, moving the decimal, or locating one, two places to the right in a square increases the square to the square of a number ten times as large, and, moving it likewise two places to the left, reduces the square to the square of a number one-tenth as large as the number, or root of the given square. Example—Take 20 as the given number:—400 is its square and 40000 is the square of 200,—200 being $20 \times 10 = 200$ and 40000 being $400 \times 100 = 40000$: likewise, 4 is the square of 2, 2 being $20 \div 10 = 2$ and 4 being $400 \div 100 = 4$. It is the same with any other number, the process being to move the point, to the right or left, as required, *one* place in the *number* and *two* places in the *square* for numbers and squares ten times greater or less than a given number. The same is true of numbers and their cubes except the point is moved *three* places to the right or left instead of two places, because; any given cube is 1000 times the cube of a number one-tenth that of the root of the given cube. If 2.8 is the given number, 21.952 is its cube; $2.8 \times 10 = 28.$ and the cube of 28. is 21952,—being $21.952 \times 1000 = 21952.0$; $28 \times 10 = 280$ and the cube of 280. is 21,952,000, which is 21952×1000.

Referring again to Table VII, the eighth column gives the length of sides of squares of area equal to the areas given opposite in the third column, that is to say the area of a circle given in column three, has for its diameter, the number given in the same line in the first column, and a square of equal area would have sides of the length given in column eight in the same line. The diameter of a circle is to the side of an equal area square as 1 is to .8862, hence the indication at the head of column eight,—**n**.8862 (the *number* [n] multiplied by 0.8862), thus: $20 \times 8862 = 17.724$; $17.724 \times 17.724 = 314.14$, while $20 \times 20 \times .7854 = 314.16$; the slight discrepancy in the foregoing is due to dropped decimals. To go a little further, taking from the table 17.7245 the result

is still closer. $17.7245 \times 17.7245 = 314.15791025$,—less than $\frac{21}{10000}$ error.

At the left in the table are given the reciprocals of the numbers in the first column, the reciprocal of a number being *one divided by the number.* The trade will probably care little for these, yet they are decimal fractions of *one*, being $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{5}$ etc., to $\frac{1}{99}$ and $\frac{1}{100}$, expressed decimally. The decimals can be translated into common fractions by always using *one* as the numerator and taking for the denominator the number of the first column in the same line; thus .025641, in line with 39, is $\frac{1}{39}$ of 1.0 because $1 \div 39 = .025641$.

Reciprocals are used to perform long division by multiplication by multiplying the dividend by the reciprocal of the divisor to obtain the quotient found in the ordinary way. If the character of the work justifies it this method is extended so far as to make it quite complex to one not versed in such practice, and there is little gained, ordinarily, unless one is familiar with the process and has an elaborate table of reciprocals at hand.

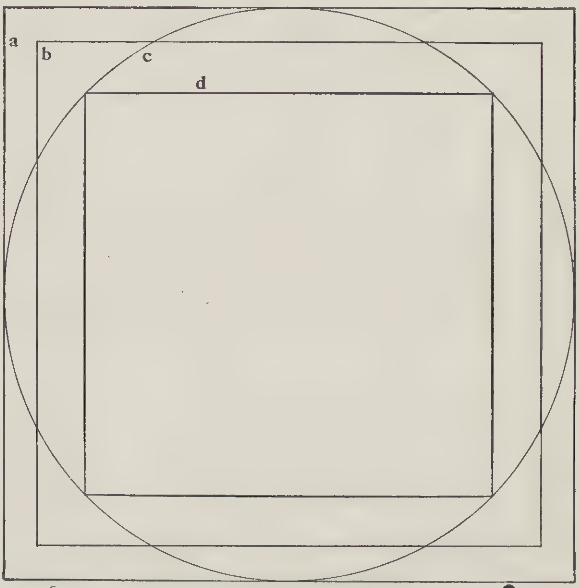


Fig. 1. Circumscribed and Inscribed Circles and Squares

Some of the tabular matter will be illuminated by reference to Fig. 1, a diagram of inscribed and circumscribed squares and circles, of which the following is true for any dimensions: **a** is a square circumscribed to circle **c**; any side of **a** is equal to the diameter of circle **c**; **b** is a square equal in area to the area of circle **c**; a side of **b** is equal to 0.8862 of **c**'s diameter,—**c** is a circle circumscribed to square **d** and inscribed to square **a**; area of **c** equals area of **b** and is equal to 0.7854 of the area of **a**;—**d** is a square inscribed to circle **c**; area of **d** equals half the area of **a**; a side of **d** equals 0.7071 if a side of **a**, or of the diameter of **c**.

The following supplements some of the data already given and also contains directions for finding most of the dimensions, areas and solidities likely to be called for in any ordinary practice. The presence of this information will save frequent reference to other books that may not be conveniently at hand.

The area of a circle multiplied by 1.273 increases it to the area of a square with a side equal to the circle's diameter.

The side of a square multiplied by .2851 gives the side of a square of equal area.

The circumference of a circle multiplied by .2251 gives the side of its inscribed square.

The side of a square multiplied by 1.414 gives its diagonal, or the diameter of its circumscribing circle.

If the circumference only is known, multiply its square by .07958 for the area.

The circumference of a circle multiplied by $\frac{1}{2}$ its radius ($\frac{1}{4}$ diameter) gives the area, nearly.

Circumference divided by 3.1416 gives the diameter of a circle.

For the area of an ellipse, multiply the major axis by the minor axis, and the product by .7854.

For the area of a washer, subtract the area of a circle equal to the size of the hole, from the area of a circle equal in diameter to that of the washer.

For the convex surface of a cone, multiply the circumference of the base by the slant height (length of slant, base to apex) and divide the product by 2; to this add the area of the end, if the whole surface is required.

For the convex surface of a cone frustum, add the circumferences of base and top and multiply the sum by half the slant height of the frustrum; to this add the area of the base and top (the ends), if the whole surface is required.

For the surface of a sphere, multiply the circumference by the diameter, or square the diameter and multiply the product by 3.1416.

For the surface of a regular pyramid, multiply the perimeter (sum of all its sides) by half the slant height (middle of one side to apex); to this add the area of the base, if the entire surface is required. To obtain area of base, divide it into triangles and find their sum.

For the surface of frustum of a regular pyramid, multiply half the sum of the perimeters of base and top by the slant height of the frustrum; to this add the area of the ends, if the whole surface is required.

For the solidity of the frustum of a pyramid: first find the sum of the area of the base, plus the area of the top, plus a geometrical mean proportional between the area of the base and that of the top; then multiply the sum, so obtained, by the altitude; one third of the product will be the solidity. The geometrical mean proportional is found by multiplying the area of the base by the area of the top and then extracting the square root of the product, which will be the *mean* required.

For the solidity of a prism, multiply the area of the base by the perpendicular height.

For the solidity of a cone, multiply the area of the base by the altitude, and divide the product by 3,—quotient is the solidity.

For the solidity of a cone frustum, first find the sum of the area of the base, plus the area of the top plus the geometrical mean proportional between the area of the base and that of the top (see above for finding the mean); multiply the sum so obtained by one-third of the altitude and the product will be the solidity.

For the solidity of a sphere, multiply its surface by one-sixth of the diameter and the product is the solidity; or, multiply the cube of the diameter by 0.5236 and the product is the solidity.

For the solidity of a cylindrical ring, add the inner diameter of the ring to its thickness and multiply the sum so obtained by the square of half the thickness; then multiply the product by 9.87,—product is the solidity.

One U. S. gallon is 231 cubic inches. 294 cylindrical inches, nearly, equal 231 cubic inches,—within less than one-tenth of a cubic inch: therefore, in finding the contents of cylinders in gallons, the error arising from squaring the diameter of the circle can, for a time, be ignored (that is, omit multiplying by .7854) and the error will be corrected by dividing the cubic inches of contents by 294 instead of 231, for U. S. gallons. This will be clear when it is remembered that the area of 1 square or cubic inch exceeds 1 circular or cylindrical inch by .2146,—the difference between 1. and .7854; .2146 per cent. of 294=63, and 294—63=231.

CHAPTER VII

Value of Sines, Tangents, Etc., in Pipe Work

Though the use of some derivative constants is every day practice, the functions of angles have ordinarily had a more limited direct application to problems of the trade than is merited, due largely, perhaps, to no one thinking it worth the while to bring the subject matter specifically to the attention of the craft. With the following brief consideration as a basis to build to, and the better understanding of some elements of the circle it may afford, many will be led to an increasingly extended use of the aid at hand through a table of natural sines, cosines, tangents and secants of the quadrant,—advancing by degrees, as given in Table VIII. At any degree given, these functions bear to the *radius* as 1.0 (unity) the relation stated, and are raised to the dimensions of the work in hand by multiplying by the radius of the circle governing in terms agreeing,—that is, if figuring in feet, multiply by the radius in feet; if in inches, multiply by the radius in inches; if in meters, by meters, etc. If the radius is 12 inches, its dimension cosine at 45 deg. is $0.7071 \times 12 = 8.4852$ inches; the tangent raised to dimensions is $1.0 \times 12 = 12$ inches,—the side of a square the side of which is equal to the radius; the secant is $1.4142 \times 12 = 16.9704$ inches,—generally taken as 17 inches, being the diagonal of a square the side of which is equal to the radius.

In pipe work the secant is always the equivalent of the offset-piece in length, whatever the degree of the fitting used. The value of any such functions for any other degree of the quadrant, for any radius in any terms is found as above indicated. The angles of pipe fittings, beginning with 90 deg., being a series in which half the angle is taken for the next lesser bend, down to $5\frac{5}{8}$ deg., sines or other elements to a fraction of a degree are required in some instances; for example, the function of an angle of $5\frac{5}{8}$ deg. or its complement, $84\frac{3}{8}$ (84.375) and of one $11\frac{1}{4}$ deg. or its complement, $78\frac{3}{4}$ deg., etc. fall between even degrees. As these can be interpolated near enough for practical work of the kind it was not thought necessary to take up room with any fractional parts, as a full table to minutes of arc only would require 60 times as much space as the table given. To interpolate roughly for the fractional part of a degree, find the difference of the function for the two degrees between which the fraction falls: divide this difference by the denominator of the fractional part and multiply the quotient by the numerator; then for the functions named in the table, excepting co-functions, *add* the product to the even degrees of the angle; for cosines, cosecants and cotangents, *subtract* the difference from the even

Table VIII. Natural Sines, Cosines, Tangents and Secants for Each Degree of the Quadrant

Degree	Sine	Cosine	Tangent	Secant	Degree	Sine	Cosine	Tangent	Secant
0	.00000	1.0000	.00000	1.0000	46	.7193	.6947	1.0355	1.4395
1	.01745	.9998	.01745	1.0001	47	.7314	.6820	1.0724	1.4663
2	.03490	.9994	.03492	1.0006	48	.7431	.6691	1.1106	1.4945
3	.05234	.9986	.05241	1.0014	49	.7547	.6561	1.1504	1.5242
4	.06976	.9976	.06993	1.0024	50	.7660	.6428	1.1918	1.5557
5	.08716	.9962	.08749	1.0038	51	.7771	.6293	1.2349	1.5890
6	.10453	.9945	.10510	1.0055	52	.7880	.6157	1.2799	1.6243
7	.12187	.9925	.12278	1.0075	53	.7986	.6018	1.3270	1.6616
8	.1392	.9903	.1405	1.0098	54	.8090	.5878	1.3764	1.7013
9	.1564	.9877	.1584	1.0125	55	.8192	.5736	1.4281	1.7434
10	.1736	.9848	.1763	1.0154	56	.8290	.5592	1.4826	1.7883
11	.1908	.9816	.1944	1.0187	57	.8387	.5446	1.5399	1.8361
12	.2079	.9781	.2126	1.0223	58	.8480	.5299	1.6003	1.8871
13	.2250	.9744	.2309	1.0263	59	.8572	.5150	1.6643	1.9416
14	.2419	.9703	.2493	1.0306	60	.8660	.5000	1.7321	2.0000
15	.2588	.9659	.2679	1.0353	61	.8746	.4848	1.8040	2.0627
16	.2756	.9613	.2867	1.0403	62	.8829	.4695	1.8807	2.1300
17	.2924	.9563	.3057	1.0457	63	.8910	.4540	1.9626	2.2027
18	.3090	.9511	.3249	1.0515	64	.8988	.4384	2.0503	2.2812
19	.3256	.9455	.3443	1.0576	65	.9063	.4226	2.1445	2.3662
20	.3420	.9397	.3640	1.0642	66	.9135	.4067	2.2460	2.4586
21	.3584	.9336	.3839	1.0711	67	.9205	.3907	2.3559	2.5593
22	.3746	.9272	.4040	1.0785	68	.9272	.3746	2.4751	2.6695
23	.3907	.9205	.4245	1.0864	69	.9336	.3584	2.6051	2.7904
24	.4067	.9135	.4452	1.0946	70	.9397	.3420	2.7475	2.9238
25	.4226	.9063	.4663	1.1034	71	.9455	.3256	2.9042	3.0715
26	.4384	.8988	.4877	1.1126	72	.9511	.3090	3.0777	3.2361
27	.4540	.8910	.5095	1.1223	73	.9563	.2924	3.2709	3.4203
28	.4695	.8829	.5317	1.1326	74	.9613	.2756	3.4874	3.6279
29	.4848	.8746	.5543	1.1433	75	.9659	.2588	3.7321	3.8637
30	.5000	.8660	.5774	1.1547	76	.9703	.2419	4.0108	4.1336
31	.5150	.8572	.6009	1.1666	77	.9744	.2250	4.3315	4.4454
32	.5299	.8480	.6249	1.1792	78	.9781	.2079	4.7046	4.8097
33	.5446	.8387	.6494	1.1924	79	.9816	.1908	5.1446	5.2408
34	.5592	.8290	.6745	1.2062	80	.9848	.1736	5.6713	5.7588
35	.5736	.8192	.7002	1.2208	81	.9877	.1564	6.3138	6.3924
36	.5878	.8090	.7265	1.2361	82	.9903	.1392	7.1154	7.1853
37	.6018	.7986	.7536	1.2521	83	.9925	.12187	8.1443	8.2055
38	.6157	.7880	.7813	1.2690	84	.9945	.10453	9.5144	9.5668
39	.6293	.7771	.8098	1.2867	85	.9962	.08716	11.4301	11.474
40	.6428	.7660	.8391	1.3054	86	.9976	.06976	14.3007	14.335
41	.6561	.7547	.8693	1.3250	87	.9986	.05234	19.0811	19.107
42	.6691	.7431	.9004	1.3456	88	.9994	.03490	28.6363	28.654
43	.6820	.7314	.9325	1.3673	89	.9998	.01745	57.2900	57.299
44	.6947	.7193	.9657	1.3902	90	1.0000	Inf.	Inf.	Inf.
45	.7071	.7071	1.0000	1.4142		—	—	—	—

degrees of the angle. Thus, for the tangent of $22\frac{1}{2}$ deg.: tangent of 22 deg. is 0.4040, and for 23 deg., 0.4245,—the difference is 0.0205; $0.0205 \div 2 = 0.01025$; $0.01025 + 0.4040 = 0.41425$, correct to four decimal places, as tangent of 22 deg. and 30 minutes. Where the function is changing length rapidly, the error is greater, as tangent for $84\frac{3}{8}$ deg.:—difference between 84 and 85 deg. tangents equals 1.9157; $1.9157 \div 8 = .2394$; $.2394 \times 3 = .7182$; 0.7182 plus 9.5144 (tan. 84 deg.) = 10.2326, tangent, so found, of $84\frac{3}{8}$ deg. (84 deg. 22 min. 30 sec.).

This is in error about $\frac{1}{128}$ of the tangent length, which should be 10.1532. Interpolation is also done by proportion, generally for seconds, with tables to degrees and minutes of arc,—60 being to the difference between the next higher and next lower function (of even degrees or minutes) as the fractional part of degree or minute is to the addition to be made even degrees or minutes. Fractional parts so found are as before *added* to *sines*, *tangents*, and *secants*, but must be subtracted from their companion functions *cosines*, *cotangents* and *cosecants*, because these latter functions decrease while the former increase from 0 deg. to 90 deg. Cotangents and cosecants are not named in the table given. The versed sine, (cosine reversed) not given, is a companion function of the cosine, growing as the cosine diminishes. Subtracting the table cosine from 1.0, the radius, leaves the versed sine. As the functions and co-functions named increase in reverse order, the elaborate tables in engineering books are arranged to save space by reading downward in 1, 2, 3, order for sines, cosines, etc., to 45 deg. inclusive, and upward, 45 deg. to 90 deg. At 45 deg. the growth of the sines from zero and the diminishing of the cosines from radius (other comparison functions likewise) have brought the values of sine and cosine to the equal of each other, and to continue the table from 45 deg. to 90 deg. would be merely to repeat the figures from 0 deg. to 45 in reverse order, transposed. The figures 0 to 45 deg. are therefore utilized as they stand, by numbering backward the same quantities, to thus be read as 45 to 90 deg. and, affixing the names, *transposed*, at the foot of the columns, putting *sine* under the cosine column, etc.

The straight reading, 0 deg. to 90 deg. given in Table VIII will be a little more convenient to those making only casual reference. Cotangents, cosecants, etc., will not be so often used by the craft, but they are contained, unmarked, in the table given, because the co-functions on which they depend are given from 0 to 90 deg. Thus if the cotangent or cosecant of, say, 53 deg. is wanted, the tangent or secant of the complement of 53 deg., (37 deg.) will be the cotangent or cosecant of 53 deg. That is, 90—53 = 37 deg. Tangent of 37 deg. is 0.7536, and is also the cotangent of 53 deg., 53 being as far removed from 90 as 37 is from 1. The value of one function often affords the means of finding that of another, thus: The sine of any angle divided by its

cosine gives a quotient equal to the tangent of that angle; the cosine divided by the sine, likewise provides the cotangent of the angle; 1.0 divided by the cosine, gives the secant, and 1.0 divided by the sine gives the cosecant.

It will be noticed that the table is marked "*natural*" sines, etc. This is to distinguish the functions from those in tables of logarithmic functions of angles of which the values, though ultimately the same, are represented by figures differing to accord with logarithmic processes. It may not be out of place to say that logarithms are a series of auxiliary numbers devised to shorten arithmetical calculation by substituting addition and subtraction for multiplication and division,—sums and differences, in logarithmic processes, being respectively the products and quotients obtained by greater labor in the ordinary arithmetical processes of multiplication and division. The logarithm of a given number is the exponent of a power to which the base number of the system would have to be raised to equal the given number. There are several systems in use. The common or Brigg's logarithms, much used, have a base of 10. The 1st, 2nd, 3rd, and 4th, powers of 10 are 10, 100, 1000 and 10000; 1, 2, 3, and 4 are the respective exponents of the powers to which 10 (the base) must be raised to equal those numbers; therefore 1, 2, 3, and 4 are the logarithms of 10, 100, 1000 and 10000 respectively. A serious consideration of logarithms with a view to setting forth their application to work would require more space than the limited use of such in the trade would justify.

All of these functions and processes will be better understood by reference to Fig. 5, illustrating some of the elements of the circle, and on which : **AC** is the diameter; **AB**, a radius; **CD**, tangent of arc **CHE**; **BD**, secant of arc **CHE**; **JD**, cotangent; **BAJ**, a quadrant; **BEJ**, a sector; **CE**, chord of arc **CHE**; **GE**, sine; **BG**, cosine, and **GC** versed sine of angle of 45 deg.; diameter **AC**, chord **MN** and arcs **AM** and **CN** bound a zone; **BALK** is a sector,—**BAK** is its sector triangle, bounded by radii **BA** and **BK** and chord **AK**, and, **AKL** is its segment, the segment being bounded by chord **AK** and arc **ALK**. At 45 deg. (the angle shown) the arc **CHE** equals, at unity, 0.7853, and its chord, **CE** equals 0.7653; at an angle of 60 deg. the arc would equal 1.047 and the chord would equal 1.0 (equal radius).

It is evident to the eye from the diagram that at 45 deg., sine and cosine are equal and that tangent and cotangent are equal; and, it is quite easy to see that at 60 deg., cosine and versed sine are equal; that decreasing the angle shortens the secant to radius, diminishes the tangent to nothing and increases the cotangent to infinity, at 0 deg.; that increasing the angle lengthens the secant and tangent to infinity and diminishes the cotangent to nothing at 90 deg.; that any chord (as **EF**) is twice the sine (**GE**) of half the angle; that the area of any sector

is to the area of the circle as the degrees embraced by its arc are to 360; that area of any segment is the area of its sector, less the area of the sector triangle; that the dimensions, of the base (sine X2) and the altitude (cosine) of the sector triangle in the terms of the work in hand are available by raising the table value by multiplying by the radius; that 90 deg. being one-fourth of the circle, and the sine of 45 deg. being 0.7071, a side of the greatest square that can be inscribed in a circle is 0.7071 per cent. of the circle's diameter.

At unity $0.017453 \times 360 = 6.28$,—the circumference of 2. The length of a circular arc of 1-degree may be taken as 0.017453. Therefore the degrees of any circular arc multiplied by 0.017453 and by the radius of the circle equals the length of the arc.

Any regular polygon may be considered as made up of as many sector triangles as there are sides, the length of the joining sides being equal to the radius of the circumscribed circle. Then for area: divide 360 by the number of sides for the degrees of the angle included by each triangle; the sine of half the angle multiplied by its cosine will then give the area of one of the triangles, which multiplied by the number of sides will give the area of the polygon, thus: a polygon has five 25-foot sides,—What is the area? The length of one side is the only data to work from in this. $360 \div 5 = 72$; $72 \div 2 = 36$ deg.,—half the angle; the sine of 36 deg. at unity (half of one side is known to be 12.5 ft.) $= 0.5878$, which is 0.5878 per cent. of the radius. $12.5 \div 0.5878 = 21.26$ ft., the radius; cosine of 36 deg. $= 0.8090$; $0.8090 \times 21.26 = 17.20$ ft., the dimension cosine or height of the sector triangle; then, by the common rule for triangles, 17.2 (the altitude) $\times$ 12.5 (half the base) $= 215$ sq. ft., the area of one triangle of the polygon; $215 \times 5 = 1075$ sq. ft.,—the areas of the polygon.

Had the area of one of the sector segments been found and multiplied by 5 and the product subtracted from the area of a circle of 42.5 ft. diameter, the result would have been the same. Also, as the area of similar regular polygons are to each other as the square of a side of one is to the square of a side of the other, the area may be closely approximated by multiplying the square of one side of a polygon by:—0.433 for 3-sided figures; by 1.0, for 4-sided; by 1.72, for 5; 2.6, for 6; 3.643, for 7; 4.828, for 8; 6.182, for 9; 7.7, for 10; 9.365, for 11-sided, and 11.2, for 12-sided polygons. Finding the area of a segment, above referred to, is as follows:—Chord is, say, 12 inches and angle 90 deg., what is the area of the segment? Sine of half the angle (45) is 0.7071 and known to be 6 inches; $6 \div 0.7071 = 8.485$, the radius; cosine of 45 deg. is also 0.7071, which, by 8.485 (the radius) $= 6.0$; 6.0 (half the base) $\times$ 6.0 (the altitude of sector triangle) $= 36$. A 90-deg. sector (quadrant) of a circle of 8.5 inch radius equals 56.75 inches area; 56.75—36. $= 20.75$, the required area of the segment.

From what has been said, the application of Table VIII functions to determine depth of water flowing in drains, superficial surface in certain roofs and spaces, area of certain cross-sections, distance of offset, projection and course of lines due to certain changes of course, etc., will suggest themselves from time to time as occasion offers.

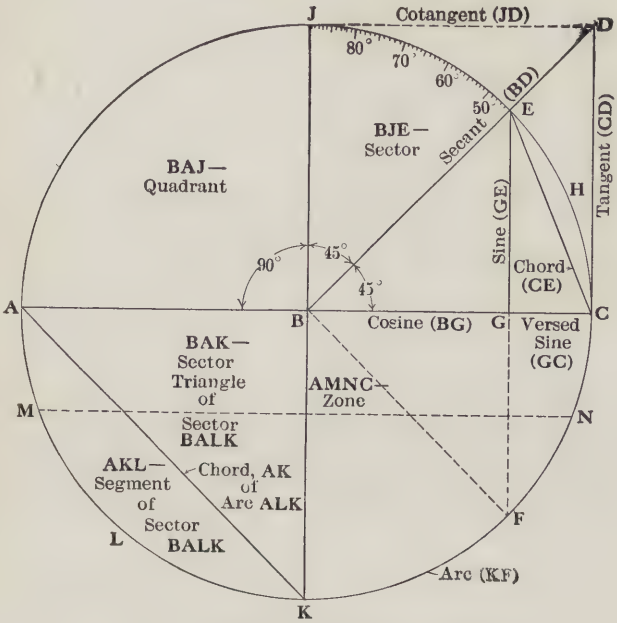


FIG. 5. SOME ELEMENTS OF THE CIRCLE

In finding angles and the length of sides of triangles, the following may prove more to the liking of those in the habit of using formulae:

$$\text{Sine} = \frac{\text{Opposite}}{\text{Hypot}} = \frac{a}{c} \quad \text{Tangent} = \frac{\text{Opposite}}{\text{Adjacent}} = \frac{a}{b} \quad \text{Secant} = \frac{\text{Hypot}}{\text{Adjacent}} = \frac{c}{b}$$

$$\text{Cosine} = \frac{\text{Adjacent}}{\text{Hypot}} = \frac{b}{c} \quad \text{Cotangent} = \frac{\text{Adjacent}}{\text{Opposite}} = \frac{b}{a}$$

$$\text{Cosecant} = \frac{\text{Hypot}}{\text{Opposite}} = \frac{c}{a}$$

Solution of Right Angle Triangle

$$\text{Sin. } A = \frac{a}{c} = \text{Cos. } B \qquad a = c \times \text{Sin. } A$$

$$c = \frac{a}{\text{Sin. } A} \qquad b = \frac{a}{\text{Tan. } A}$$

$$\text{Cos. } A = \frac{a}{b} = \text{Cot. } B \qquad a = b \times \text{Tan. } A$$

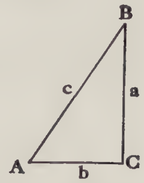


FIG. 6. RIGHT-ANGLED TRIANGLE

$$\text{Tan. } \mathbf{A} = \frac{\mathbf{a}}{\mathbf{b}} \qquad \text{Cot. } \mathbf{A} = \frac{\mathbf{b}}{\mathbf{a}} = \text{Tan. } \mathbf{B}$$

$$\mathbf{a} = \sqrt{(\mathbf{c}-\mathbf{b})(\mathbf{c}+\mathbf{b})} \qquad \mathbf{b} = \sqrt{(\mathbf{c}+\mathbf{a})\ (\mathbf{c}-\mathbf{a})}$$

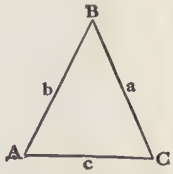


FIG. 7. OBLIQUE-ANGLED TRIANGLE

Solution of Oblique Triangles

Case I. When a side and two angles are given:

$$\mathbf{c} = 180° - (\mathbf{A}+\mathbf{B}) \qquad \mathbf{a} = \frac{\mathbf{c}\text{ Sin. }\mathbf{A}}{\text{Sin. }\mathbf{C}} \qquad \mathbf{c} = \frac{\mathbf{a}\text{ Sin. }\mathbf{C}}{\text{Sin. }\mathbf{A}}$$

$$\mathbf{b} = \frac{\mathbf{a}\text{ Sin. }\mathbf{B}}{\text{Sin. }\mathbf{A}}$$

$$\text{Sin. }\mathbf{A} = \frac{\mathbf{a}\text{ Sin. }\mathbf{C}}{\mathbf{c}} \qquad \text{Sin. }\mathbf{B} = \frac{\mathbf{b}\text{ Sin. }\mathbf{A}}{\mathbf{a}} \qquad \text{Sin. }\mathbf{C} = \frac{\mathbf{c}\text{ Sin. }\mathbf{A}}{\mathbf{a}}$$

Case II. When two sides and the angle opposite to one of them are given:

$$\mathbf{A}+\mathbf{B} = 180° - \mathbf{C} \qquad \mathbf{C} = 180° - (\mathbf{A}+\mathbf{B}) \qquad \mathbf{c} = \frac{\mathbf{a}\text{ Sin. }\mathbf{C}}{\text{Sin. }\mathbf{A}} \qquad \mathbf{b} = \frac{\mathbf{a}\text{ Sin. }\mathbf{B}}{\text{Sin. }\mathbf{A}}$$

$$\mathbf{a} = \frac{\mathbf{b}\text{ Sin. }\mathbf{A}}{\text{Sin. }\mathbf{B}}$$

$$\text{Sin. }\mathbf{A} = \frac{\mathbf{a}\text{ Sin. }\mathbf{B}}{\mathbf{b}} \qquad \text{Sin. }\mathbf{B} = \frac{\mathbf{b}\text{ Sin. }\mathbf{A}}{\mathbf{a}} \qquad \text{Sin. }\mathbf{C} = \frac{\mathbf{c}\text{ Sin. }\mathbf{A}}{\mathbf{a}}$$

Case III. When two sides and the included angle are given:

$$\mathbf{A}+\mathbf{B} = 180° - \mathbf{C}$$

$$\mathbf{a} = \frac{\mathbf{b}\text{ Sin. }\mathbf{A}}{\text{Sin. }\mathbf{B}} \qquad \mathbf{b} = \frac{\mathbf{a}\text{ Sin. }\mathbf{B}}{\text{Sin. }\mathbf{A}} \qquad \mathbf{c} = \frac{\mathbf{a}\text{ Sin. }\mathbf{C}}{\text{Sin. }\mathbf{A}}$$

$$\text{Sin. }\mathbf{A} = \frac{\mathbf{a}\text{ Sin. }\mathbf{B}}{\mathbf{b}} \qquad \text{Sin. }\mathbf{B} = \frac{\mathbf{b}\text{ Sin. }\mathbf{A}}{\mathbf{a}} \qquad \text{Sin. }\mathbf{C} = \frac{\mathbf{c}\text{ Sin. }\mathbf{A}}{\mathbf{a}}$$

Case IV. When the three sides are given:

$$\mathbf{S} = \tfrac{1}{2}(\mathbf{a}+\mathbf{b}+\mathbf{c})$$

$$\mathbf{r} = \sqrt{\frac{(\mathbf{S}-\mathbf{a})\ (\mathbf{S}-\mathbf{b})\ (\mathbf{S}-\mathbf{c})}{\mathbf{S}}}$$

$$\text{Tan. }\tfrac{1}{2}\ \mathbf{A} = \frac{\mathbf{r}}{(\mathbf{s}-\mathbf{a})} \qquad \text{Tan. }\tfrac{1}{2}\ \mathbf{B} = \frac{\mathbf{r}}{(\mathbf{s}-\mathbf{b})} \qquad \text{Tan. }\tfrac{1}{2}\ \mathbf{C} = \frac{\mathbf{r}}{(\mathbf{s}-\mathbf{c})}$$

CHAPTER VIII

Wrought Pipe Fitting Offsets

But few plumbers serve long, especially where there is considerable wrought drainage work, without finding it expedient to inquire more particularly into the functions of the angles to which pipe fittings are made. To dig in the tables is harder work to many than pipe fitting, and it is seldom convenient to do so when the data is most needed, yet the *constants* generally familiar to workmen are not extensive enough to meet the call for such aids in practical fitting.

The following tabulation contains all the *constant multipliers* likely to be called for in common work.

Fitting angle, degrees	Constants: Multipliers for diagonals	Constants: Multipliers for projections
60	1.150	0.57
45	1.414	1.00
30	2.000	1.73
$22\frac{1}{2}$	2.610	2.41
$11\frac{1}{4}$	5.120	5.03
$5\frac{5}{8}$	10.200	10.15

The relation of the above multipliers to the offset distances may be considered absolute,—that is, no matter how great or small the offset, the length of the offset-piece, from center to center of fittings, is found by multiplying the distance the pipe is to be offset by the constant multiplier for diagonals given in the table for the angle of fitting to be used. Likewise, the offset distance multiplied by the projection constant given in the table for the angle of fitting to be used always gives the projection of the pipe "run" forward, due to or resulting from making an offset with fittings of that degree.

Examples:—Pipe is to be offsetted 9-in. with 60 deg. fitting; what is the length of the diagonal piece, center to center of fitting, and how much will the offset extend or project the line of pipe forward? 9-in. $\frac{3}{4}$-ft.; $\frac{3}{4}$ ft. decimally expressed, equals 0.75; the constant multiplier for a diagonal at 60 deg. is 1.15; $1.15 \times 0.75 = 0.8625$ ft. One inch equal $8\frac{1}{3}$ per cent. of a foot or 0.0833; $0.8625 \div 0.0833 = 10.35$, which is the length, in inches, of the offset-piece. Then, for the projection; the constant multiplier for projection, when the offset is made with 60 deg. fittings, is 0.57 and $0.57 \times 0.75 = 0.4275$ ft.; $0.4275 \div 0.0833 = 5.12$-in., which is the forward projection of the pipe line in inches.

The diagonal multipliers in the table are derived by dividing the cosine (offset) of the complementary angle into the versed sine and

adding 1 to the quotient. Thus, for constant 5.12 for $11\frac{1}{4}$ deg. fittings, the complementary angle is $78\frac{3}{4}$ deg. and the cosine for $78\frac{3}{4}$ deg. is 0.195, which divided into the corresponding versed sine, 0.8049, equals 4.12 and, $4.12+1=5.12$, the constant given for $11\frac{1}{4}$ deg. fittings. A projections constant is also the secant of the angle or the reciprocal of the cosine and may also, therefore, be produced by dividing the excess of diagonal length over the offset length by the distance offsetted and adding 1 to the quotient. Should it be desired to know what distance a certain length of pipe, used as a diagonal piece, will offset a line with certain fittings, divide the constant for the fitting angle into the given length (length of the piece),—the quotient will be the offset distance.

The projection of the line of pipe resulting from offsetting is represented by the sine (or by the tangent) of the angle. The projection constants are derived by dividing the cosine (offset), of the angle complementary to the angle of the fitting, into the corresponding sine (projection). Thus, taking $78\frac{3}{4}$ deg., given above, the cosine is 0.195, the sine is 0.9807, and $0.9807 \div 0.195 = 5.029^{+}$or 5.03, as given in the table.

Various circumstances give these projection constants a value as aid on practical work, though they have been little used by the majority of mechanics. For an instance of the common need for them, let us suppose a line of pipe is to be offsetted to dodge an obstruction, and that a branch in the line before the offset, or other reason, gives cause to doubt whether we can clear the obstruction with fittings of a given angle with offset beginning at a given obligatory point; then, if we take the distance from given point to obstruction as the projection of the line and *divide* it by the projection *constant* given for the degree of fitting it is proposed to use, the quotient will be the offset for that projection distance and show whether fittings of the proposed angle are suitable; if not, fittings with a greater angle must be used.

All of the foregoing is made clearer by reference to Fig. 10 which is drawn and lettered with a view to making it most easily understood. The functions and offsets indicated would be proportional and bear the same relation to each other at any radius. This is graphically shown to some extent by the small radius arc, **W-X**, and its sines to the same angles as those of the larger quadrant, dotted in to cut radius **W-A**.

It will be noticed that when pipe offsets are laid upon a quadrant, in regular order as shown, the fitting angles grow from **Z** in the direction of **Y**, while the degrees of the arc giving the functions from which the constants are derived grow from **Y** to **Z**. It is, therefore, the complementary angles instead of the angles of the fittings, that name the sines, cosines, etc., referred to. For this reason the fitting angles were marked, inside the dotted arc, growing from **Z** and their complementary angles placed opposite, outside the arc line and growing from **Y**. At 45 deg. the fitting angle, its complement and their functions are the

same,—**F-f**, being the sine; **F-A**, the cosine; **F-Y**, the versed sine, and **A-f**, (considered from **A** to the tangent **U**) the secant. The secant is generally called "diagonal" when speaking of pipe offsets made with other than 90 deg. fittings. The other sines, etc., are lettered similarly.

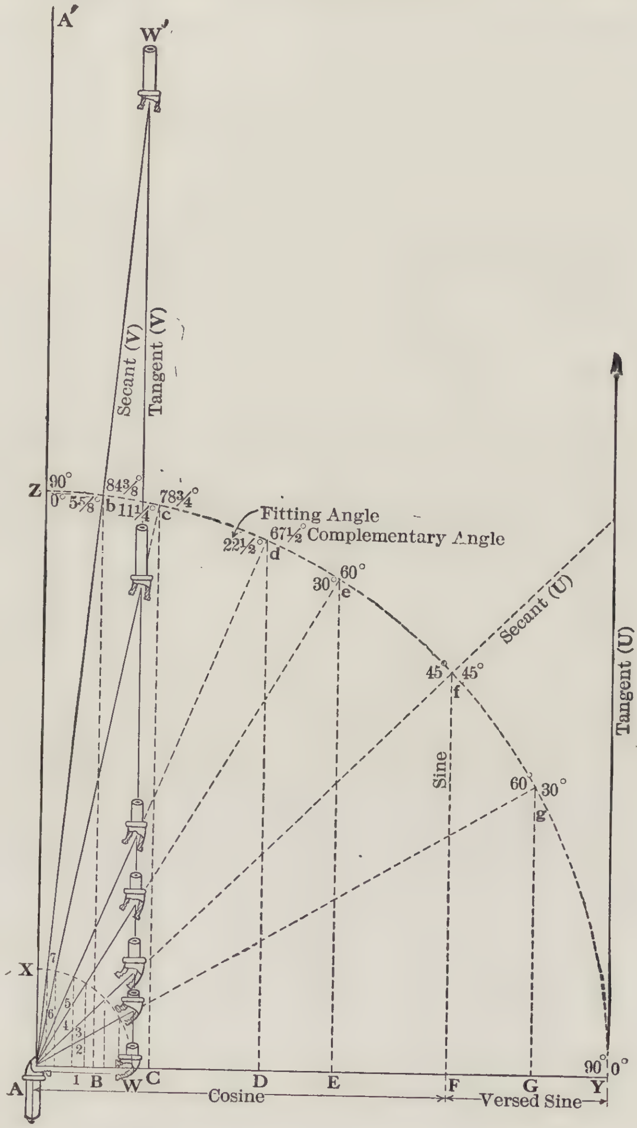


FIG. 10. FUNCTIONS OF ANGLES IN MEASURING OFFSET PIECES

Fitting angles, designations, and complementary angles for all standard bends are tabulated below, the fractions given under "bend"

being tne arc of the circle the bend is equal to, and the complementary angles being the number of degrees, which added to the fitting angle make 90.

Bend	Fitting Angle	Complementary Angle
$\frac{1}{6}$	60	30
$\frac{1}{8}$	45	45
$\frac{1}{12}$	30	60
$\frac{1}{16}$	$22\frac{1}{2}$	$67\frac{1}{2}$
$\frac{1}{32}$	$11\frac{1}{4}$	$78\frac{3}{4}$
$\frac{1}{64}$	$5\frac{5}{8}$	$84\frac{3}{8}$

Drawing all the fittings in to the same, small offset distance, permitted illustrating the relative distances at which the secants intersect the tangent in offsets of like distance. **W-W**^{1} is tangent to the arc **W-X** and is the projection (sine or tangent) for the offset (secant) **A-W**^{1}. If the offset distance was **A-Y** instead **A-W**, the secant or offset-piece would be 10.2 times **A-Y** instead of 10.2 times **A-W** as shown. Likewise, secant number 3 for the angle of 45 deg., taken to the intersection of tangent **W-W**^{1} is 1.414 times **A-W**, but if the offset is increased to **Y**, the secant number 3, or **U**, from **A** to intersection with tangent **U**, will be 1.414 times **A-Y**; that is, if **A-Y**=1-ft., secant **U**, from **A** to the intersection of tangent **U**, will be $1 \times 1.414 = 1.414$ ft. or 16.97 inch, practically 1-ft. 5-inches.

As any offset-piece is the hypothenuse oi a right angled triangie, the length is easily found arithmetically by extracting the square root of the sum of the squares of the offset and projection. But it is much easier to use the constants, especially for projections. They can be set in a pocket memo book until one is able to trust them to memory.

CHAPTER IX

Linear Expansions of Pipe, and Metal Tape Lines

Dulong and Petit determined the length of an iron bar to have increased to 1.00118203, at 100 deg. C. when the length was 1.0 at zero, Centigrade,—a linear expansion practically equal to $\frac{1}{846}$ of its unit length for the 100 deg. C. added temperature; $.00118203 \times 846 = 0.99999738$. The experiments of Messrs. Calvert, Johnson and Lowe, gave the expansion of wrought iron, for the same range of temperature as 0.00119, their results for several metals being, for a temperature rise of 100 deg. C., (0 to 100) an increase over the unit length of: for commercial aluminum, .00222; pure antimony, .00098; pure bismuth .00133; wrought iron, .00199; cast iron, .00112; soft steel, .00103; pure gold, .00138; pure lead, .00301; pure tin, .00273, and for pure forged zinc, .00220.

Now, it may appear to some that decimals so small as $\frac{1}{100}$ of any of the above are too little to be of any consequence to a pipe fitter, but their importance can be proved by measuring and marking quickly before the line has a chance to expand, a stretch of hot pipe with a steel tape; then let the tape lay upon the pipe a little to give it the temperature of the pipe, after which measure again and note how much too long would be a new piece cut to measure, cold, with a cold tape if measured for carelessly on a hot pipe with a cooler tape.

In Fig. 15 are a series of four comparisons, **A**, **B**, **C** and **D**, illustrating the above. Length **M^1-M** equals the expansion. Point **M** moving to **M^1** would bring the *correct* measure graduation to **M** position while hot,—this would on cooling shrink to **M^2** position, the cold length that would assume **M** position when hot. The result in the work will be the same whether the measure be taken with a stick, linen tape or steel tape.

To apply the expansion of iron for the unit length for 100 deg. C in degrees F., take the above increase 0.00119 as a basis; if the unit length be taken to be 1-in., the linear expansion for 100 deg. C. for 1-in. length will be 0.00119-in. The temperature rise for this increase is 100 deg. C. One degree C. $= \frac{9}{5}$ deg. F.; 0.C. = 32 deg. F. 100 deg. C. = 180 deg. F. 180 plus 32 (32 = the dif. F. deg. between C. and F. zero) = 212 deg. F. Then, $100 \div 5 = 20$; $20 \times 9 = 180$; $0.00119 \div 180 = 0.00000661$, the linear expansion per inch per F. deg. The same result is obtained by reducing the C. degree expansion to $\frac{5}{9}$ instead of converting the degrees, as follows: $0.00119 \div 100 = 0.0000119$; $0.0000119 \div 9 = 0.000001322$; $0.000001322 \times 5 = 0.00000661$, the expansion per inch, per F. degree, as above. Therefore, $0.00000661 \times 12 = 0.00007932$, the

linear expansion per foot, per F. degree. For actual work, the author corrects this last decimal to 0.00008, and then for short ignores the cyphers and simply multiplies by 8 and then, because of the cyphers, points off in the product, 5 places for the multiplier, plus as many decimal places as there are used decimal places in the multiplicand.

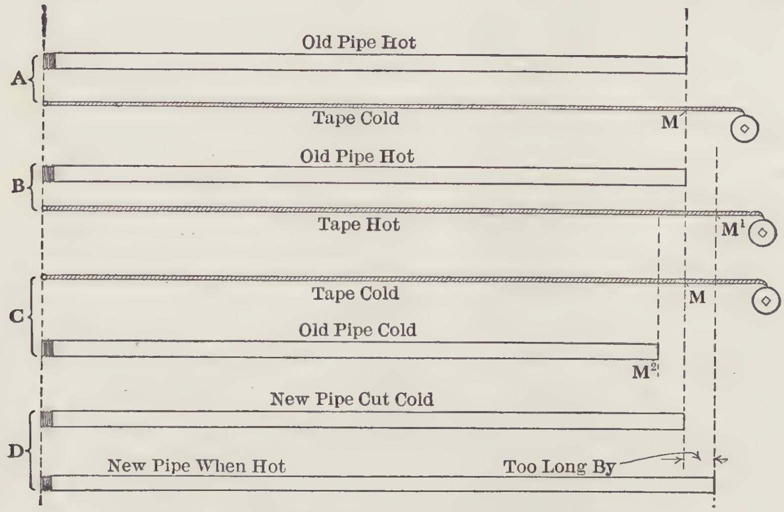


FIG. 15. TEMPERATURE ERRORS IN PIPE CUTTING

The same decimal can be used in the same way for correcting tape lines for change of temperature, as well as for finding the length of cold pipe to equal the cold length of a pipe measured hot, say as when renewing a length, or breaking a line to put in a branch, where the preparation for inserting must be made before hand, or where old pipe, hot, in place, must be measured in service and discounted in making up a new run or change of connections.

For example: a pipe line is measured at 70 deg. F. and found to be 90 ft. 6 in. long,—how long will it be at 215 deg. F.? 215—70 = 145; 145 × .00008 = .0116-in. expansion for 1-ft. for the range, and 0.0116 × 90.5 (90 ft. 6 in.) = 1.0498 inches, say $1\frac{1}{20}$-in. expansion, or 90 ft. $7\frac{1}{20}$-in. long at 215 deg. F. The same result is obtained as follows: 90.5 × 0.00008 = 0.00724; 0.00724 × 145 = 1.0498,—equal $1\frac{1}{20}$-in. The same would be true of a tape for equal change of temperature. For a decrease of temperature find the expansion element and deduct it. For expansion from temperate weather, say 60 deg. F., to low pressure steam temperature, each 10 ft. of pipe lengthens about $\frac{1}{8}$-in.—this is the allowance commonly made.

The following *foot* multipliers for the range of temperature for ranges from zero, 32 and 60 deg. F. to temperatures corresponding to various steam pressures will be useful:

Table IX. Range Expansion Multipliers

Steam Gauge Pressure, lbs.	To	Expansion in inches for 1-ft. for the range when heated From		
	Deg. F.	Zero F.	32 deg. F.	60 deg. F.
3	222	0.01776	0.01520	0.01296
5	227	0.01816	0.01560	0.01336
10	240	0.01920	0.01664	0.01440
20	259	0.02072	0.01816	0.01592
30	274	0.02192	0.01936	0.01712
40	287	0.02296	0.02040	0.01816
75	320	0.02560	0.02304	0.02080
100	338	0.02704	0.02448	0.02224

When the range is the same or approximates a rise for which a multiplier is given in the table, multiply the feet length of pipe for which the expansion is desired, by the multiplier given; the product will be the increase in length. If the expanded length after heating from a given temperature to a given temperature is wanted, add the expansion element, obtained as above directed, to the pipe length at the lower temperature. Thus, 100 ft. from 32 to 338 deg. F. expands 2.448 inches, —the expanded length of pipe = 100 ft. plus 2.448 inches.

CHAPTER X

Vernier Scales

When there is occasion for very close measuring, a vernier scale of some type is handy. They are oftenest used by the trade in finding the thickness of sheet lead, tin, traps, pipe, etc. The use of the commonest vernier scales is not yet so general with the trade as to make a brief reference to them out of place here. The sketches herewith are from a paste-board model and illustrate the principles of a common type of vernier caliper that may be had graduated in inches or metric measure. Fig. 17 shows the graduations of the scales enlarged. The improvised instrument fairly represents the real tool as shown by Fig. 18. In Fig. 17 ten spaces are graduated on the vernier, or sliding jaw, each being $\frac{1}{10}$ less than the spaces graduated on the rigid jaw. They therefore aggregate nine spaces on the rigid jaw. The effect of making the vernier spaces $\frac{1}{10}$ shorter than those of the principal scale

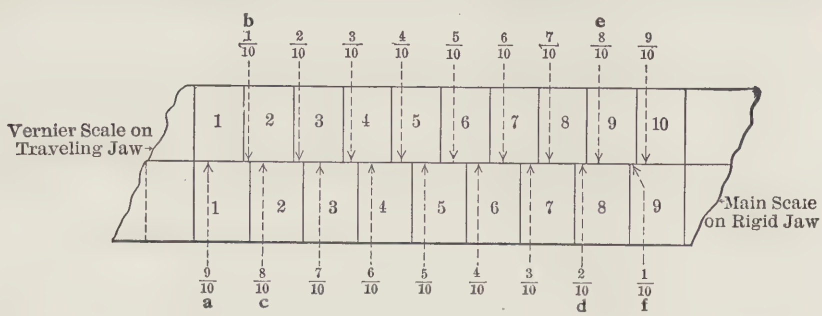


FIG. 17. READING TENTHS OF THE UNIT IN HUNDREDTHS

is to make tenths readable in hundredths of the unit. The figures on the enlarged scale show plainly that one vernier space measures but $\frac{9}{10}$ of one space on the rigid jaw; two, $\frac{2}{10}$ less than two on the rigid jaw, and so on, to nine, which cover 8 spaces on the main scale and $\frac{1}{10}$ over the ninth space, the tenth vernier space measuring the remaining $\frac{9}{10}$ of the ninth main scale space. By studying the figures on the scales of Fig. 17, it will soon be apparent that this arrangement divides the spaces (tenths) graduated on the fixed jaw into *tenths*. The graduations of the two scales agree at the right and left; then, space 1, from mark to mark, represents: **a** $=\frac{9}{10}$ and **b** $=\frac{1}{10}$ of the first main scale space; **b** $=\frac{1}{10}$ and **c** $=\frac{8}{10}$ of a main scale space; together, **b** and **c** $\frac{10}{10}$ or 1.0 of the vernier spaces,—$\frac{9}{10}$ of a main scale space. At 8, main scale, **b** $=\frac{2}{10}$ and **c** $=\frac{8}{10}$ of the space; 9, vernier, covers, as shown by **f**, $\frac{1}{10}$ of 9, main

scale, and 10, of the vernier, covers the remaining $\frac{9}{10}$ of 9, main scale. **b** and **f** are each $\frac{1}{100}$ of the main scale unit, and with perfect agreement at 1, the vernier loses $\frac{1}{10}$ of a main scale space in each division so that agreement of the two scales is again perfect at the end of the tenth vernier space.

It is obvious that upon calipering the width or the diameter of an object, if the scales are found to set as shown in Fig. 17,—that is, with the extremes of the vernier agreeing with graduations on the fixed jaw—the measurement should be read entirely from the fixed jaw, just as though there was no vernier scale above it. Whether the main scale is in inches or metric units, a vernier like shown always divides the main scale *tenths* into hundredths of the unit.

Some verniers have four times the number of spaces shown and read to much smaller fractions. They are called *direct* when the vernier spaces equal one less than the number of spaces on the principal scale, and *retrograde* when the vernier scale divisions exceed those of the main scale unit by one.

With an instrument on the plan of Fig. 18, if the position shown is the result of calipering an object, and the principal scale is in inches and

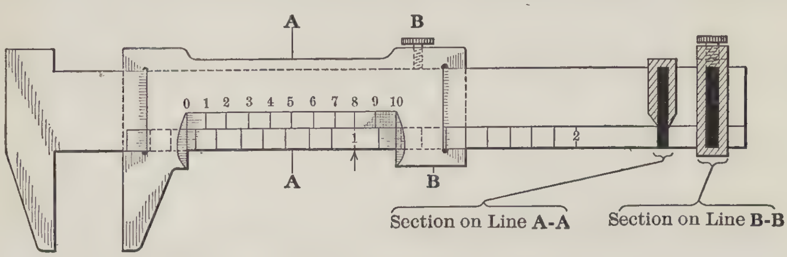


FIG. 18. DEMONSTRATING THE PRINCIPLES OF VERNIER CALIPERS

tenths, the size would read as follows: counting back from 1-inch it is easy to guess that the jaws are open about two and three-quarter spaces or tenths. The precise fractional space is determined from the vernier by counting off its spaces from 0 to the point where the vernier line coincides with the main scale line. Perfect agreement of the two scales is found to occur, in this instance, at number eight,—eight spaces from 0—thus showing the fractional space of the main scale graduation included in the measurement to be $\frac{8}{10}$. The total measure is therefore $0.2\frac{8}{10}$ inches, or 0.28,—3 hundredths more than a $\frac{1}{4}$-inch.

A little study of the sketches, with what has been said, should enable anyone to read any vernier caliper used for ordinary purposes.

CHAPTER XI

Thermometer Readings Compared

Temperatures in one connection or another are so frequently encountered expressed other than in Fahr. degrees, that, while a full table of comparisons may not be worth while, some directions for converting C. and R. degrees into F., and vice versa will not be out of place, as follows in Table X:

Table X. Data Relating to Thermometric Scales

	Fahr. deg.		Centigrade deg.		Reaumer deg.
A boiling point of fresh water (at atmosphere)	212	=	100	=	80
B freezing point of fresh water	32	=	0	=	0
C freezing point of salt water	0	=	—18	=	—14.4
Fahrenheit, at	—40	=	—40	=	—32
No. deg. **A** to **B** equals	180	=	100	=	80
No. deg. **A** to **C** equals	212	=	118	=	94.4
Deg. compared	9	=	5	=	4
To convert F. deg.: Divide by 9 and multiply by	0	by	5 for C. deg., and by		4 for R. deg.
To convert C. deg.: Divide by 5 and multiply by	9 for F. deg.	by	0 for C. deg., and by		4 for R. deg.
To convert R. deg.: Divide by 4 and multiply by	9 for F. deg.	by	5 for C. deg., and by		0 for R. deg.

After converting C. or R. deg. to F., 32 must be added to make the reading express the corresponding temperature in F. deg. If F. deg. are to be changed to C. or R. deg., first subtract 32,—then convert as above directed.

Why the centigrade and Fahrenheit thermometer scales agree at 40 deg. may be understood thus: 1 deg. C. = 1.8 deg. F. or $\frac{9}{5}$ F. deg. 1 deg. F. = 0.5555 C. deg. or $\frac{5}{9}$ C. deg.; 40 C. = 40 × 9 = 360 F. deg. *fifths*, which divided by 5 = 72 deg. F. Therefore, at 72 deg. F. below C. zero the scales agree. F. zero is 32 deg. below C. zero, and 72—32 = 40; 32 deg. F. freezing to zero F. plus 40 minus = 72 deg. F. and C. temperature below zero C., 0 to 40 = 72 deg. F., showing 40 deg. F. to be the same temperature as 40 deg. C.

When reading trade miscellany, one encounters more or less reference to *absolute zero* and *absolute temperature*, as well as absolute pressure. Absolute zero is reckoned from the following: Fluids shrink or expand according as they receive or part with heat. The rate of shrinkage for perfect gases at constant pressure is about $\frac{1}{460}$ of the unit volume per F. deg., or $\frac{1}{273}$ per C. deg. 32 deg. F. corresponds to 491 F. absolute temperature, and 460 deg. F. below zero appears, from the volume being

theoretically obliterated, to be the limit of contraction, and is the temperature assumed to be absolute zero, from which absolute temperatures are reckoned in determining adiabatic and isothermal values. In converting F. readings into absolute temperature, plus readings are added and readings below zero subtracted from 460.

CHAPTER XII

Humidity of the Air

Plumbers will find various calls for a knowledge of the amount of water vapor air is capable of holding at various temperatures. From the great increase in the capacity of air for moisture as the temperature increases it is often erroneously presumed that the humidity of winter atmosphere is much lower than that of summer. The average of winter and of summer humidity fall so close to the annual mean that the range is too small to take notice of for the applications the trade would ordinarily make. For a certain locality in the middle eastern states, the author remembers the figures to be: winter average, 74; summer average, 60; annual mean, 67. 70 per cent. is easily used in figuring and probably would never be far wrong outside the districts of extreme wet and dry. The amount or weight of vapor required to saturate a given volume of air varies according to Table XI taken from Prof. Carpenter.

Table XI. Approximate Weight of Water Vapor, in Grains, Required to Saturate One Cubic Foot of Air at Temperatures Given

Temperature air, F. deg.	**10**	**15**	**20**	**25**	**30**	**32**	**35**	**40**	**45**	**50**
Grains vapor per cu. ft.	1.1	1.31	1.56	1.85	2.19	2.35	2.59	3.06	3.61	4.24
Temperature air, F. deg.	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**
Grains vapor per cu. ft.	4.97	5.82	6.81	7.94	9.24	10.73	12.43	14.38	16.60	19.72
Temperature air, F. deg.	**105**	**110**	**115**	**130**	**141**	**157**	**170**	**179**	**188**	**195**
Grains vapor per cu. ft.	22.0	25.5	30.0	42.5	58.0	85.0	112.5	138.0	166.0	194.0

Relative humidity, determined by hair Hygrometer, dry and wet bulb thermometers, etc., is the percentage of moisture held at the time of test, contrasted with the weight of moisture in saturated air of the same temperature. A hair shortens by absorption of moisture; a wetted thermometer bulb cools by evaporation. These facts are made use of in determining humidity. In the wet bulb method, the range of cooling increases with the dryness of the air, the relative humidity varying about, from .90 per cent. to dry in from 1 to 11 deg. difference between the wet and dry bulb, with the dry bulb registering 32 deg. (1-deg. dif. indicating 0.90 relative humidity); .95 to dry in from 1 to 22 deg. at 60 deg., and from .95 per cent. humidity at 1 deg. difference to .14 per cent. at 30 deg. difference between the wet and dry bulbs when the temperature of the dry bulb is 90 deg. F.

According to Table XI, saturated air contains, per cubic-foot, 1.1 gr. of vapor at 10 deg. F., 6.84 gr. less than would saturate it at 70 deg. F. 1.1 gr. is 0.1385 per cent. of 7.94 gr. Therefore when air contains but

1.1 gr. of vapor per cubic-foot at 70 deg., its relative humidity is 0.1385 per cent.,—saturation being always taken as 100. It may thus be inferred that even when summer humidity is low, it may still contain much more vapor than would saturate it at a lower temperature.

To use the table in a likely way: 15000 cubic feet of fresh air per hour are to be brought into a house; the outer air is 10 deg. F. and its humidity is .70; the humidity is to be raised to equal 70 per cent. when the temperature is 70 deg. F.; how much water vapor per hour is required and what daily capacity should the evaporator have? $1.1 \times 0.70 = 0.77$; $7.94 \times 0.70 = 5.558$; $5.558—0.77 = 4.788$ gr. per cubic foot to be added; $4.788 \times 1500 = 7182$ gr. needed per hour; $7182 \times 24 = 172368$ gr.; $172368 \div 7000$ (gr. per avoir. lb.) $= 24.6$ lb. or 0.4 lb. less than 3 gals. for the day's evaporation.

The vapor passing out at the end of a 4-in. vent stack is assumed to be about 16.6 lb., or 2 gals. per day of 24 hours. What is the probability of that amount of vapor choking a 4-in. pipe by frost during cold weather? At the vent end, something like $\frac{1}{10}$th-in. adjacent to the circumference, say $\frac{1}{10}$th of the area, may be taken as constituting the depositing area; in this envelope of the contents impinging on the rim of the hub, as it expands outward, say of the 17 lbs. of water per day of 24 hours, $\frac{1}{10}$th or 1.7 lbs. would have a chance to congeal to the hub rim. Expansion cools the air,—a step toward the dew-point. If the dew-point is passed the latent heat of the vapor condensed is liberated and the tendency to further condensation is counteracted and the source of ice checked during cold weather periods. The higher temperature over roofs of heated buildings is also against frost, and the sun's heat tends to remove any frost that forms at night. During the unfavorable hours of a severe spell of weather, under these conditions, probably not more than a $\frac{1}{3}$-lb. of vapor would be frozen and most of it would vaporize again during the favorable hours of the day. At night when conditions are most in favor of depositing, the stack dries out from non-use and the water available for vapor is thus much reduced, and, the higher temperature of the vent-air resulting makes for its escape without depositing much vapor on the hub.

A loss of heat from air lessens its capacity for moisture; when the point of saturation is reached, further cooling causes deposition. The temperature of deposition marks the dew-point. The vapor deposited from vent pipe air gives up its latent heat and raises the temperature of the adjacent air and thus raises or holds it above the dew-point for a time, when cooling or recooling causes further deposition. The effect of cooling by expansion is well illustrated by ice forming in the ports of air motors because of expansion lowering the temperature, even to zero, where preheating is not resorted to. In soil vents, however, there is no high pressure to create such reduction of temperature; but if any

frost is formed, neither is there a high velocity, as in power work, to mechanically restrict its adherence. Mist in suspension or adhering, may, through the liberation of heat by its formation, aided by the sun in daytime, extra heat over the roof, and reduced vapor at night, check and hold off the formation of ice in the mouth of a vent to such an extent as to tide over severe cold spells without appreciable reduction of an unenlarged vent of 4-in. or more diameter, regardless of the height of the stack.

In soil-pipe ventilation if the air reaches dew-point it is as before intimated principally near the wall of the pipe or hub and is due to cooling from expansion at the point of increase, generally at the top, the plain or hub end making it possible for the outer surface of the current to be contracted to the dew-point while yet in the neighborhood of the metal. Enlarging a vent below the top and above the heated portion of a stack cools the contents *in* the pipe and favors deposition at the outlet. The safest plan is therefore to not increase vents 4-in. or larger; to place no hub at top end, and to increase small pipes to 4-in. low down in the line in order to get the benefit of house warmth above the increaser.

Just how to handle each case must be figured out by the plumber in charge, because atmospheric humidity, temperature of the pipe surface, percentage of dry interior, hours of partial dryness, and amount of available heat diverted, will always be too problematical to permit the application of a general rule. Deductions from theoretical premises will still vary from actual performance according to the errors of assumption, but it is the best one can do.

The velocities given in Table XII may be used for the temperature differences between stack and atmospheric air for the heights of stack indicated:

Table XII. Air Velocity in Feet per Minute in Vent Pipes, Due to Height of Stack and Difference Between Temperature of Air in Stack and that of Atmosphere

Diameter of Stack, inches		2	3	4	5	6
20 deg. F. dif.	Stack 20 ft. high, velocity ft. per min.....	113	135	148	168	190
	Stack 50 ft. high, velocity ft. per min.....	167	213	234	187	212
25 deg. F. dif.	Stack 20 ft. high, velocity ft. per min.....	118	151	166	187	212
	Stack 50 ft. high, velocity ft. per min.....	184	238	262	297	335
30 deg. F. dif.	Stack 20 ft. high, velocity ft. per min.....	129	165	181	205	232
	Stack 50 ft. high, velocity ft. per min.....	204	260	287	325	367

For heights of stack falling between 20 and 50 ft. high, add a proportional advance to the velocity corresponding to the difference for a 20-ft. stack, thus: for a 5-in. stack 35 ft. high at 25 deg. difference, 35 being 50 per cent. of the advance to 50 ft. over 25 ft. height of stack, 297—187=110; 110÷2=55; 187+55=242 ft. velocity per minute.

Fair estimates for plumber's purposes may be made in the same way for stacks up to 100 ft. high by adding a proportional increase over the velocity given for 50 ft. stacks.

CHAPTER XIII

Thread Standards

Much could be said of thread standards that, while true, would be of little value to the reader, but there is more or less data that is not only interesting but instructive, for there is a uniformly singular lack of information about threads in the literature of the trade.

Any size of any form of thread, right or left, can be cut on stock of any size, with a single point in a geared lathe which affords the opportunity of holding the tool rigid, and of carrying it forward or backward at a definite rate per revolution of the stock equal to the pitch of the thread required. Of course, the tool must be properly ground, and to the angle of the form of thread to be cut, and should be set (*ground so it can set*) with the cutting face in the neighborhood of 15 deg. departure downward, from the course of the radius line reaching from center to point of contract. Every person may not know these particular points offhand, but every mechanic *does* know that any machinist can cut any size or kind of thread, inside or outside, *without taps or dies*, and, that he (the workman) is at times, placed in an embarrassing position, in case of emergency, in the sense of not knowing just what to do, or what to say, or in having to give instructions as to what he wants to others who may know more in general of the subject than he does. Therefore, no live apprentice is contented with knowing merely that certain dies of the set will thread certain sizes of pipe. Both experience with and reference to, tell him there are different kinds of threads and that there is some definite relation of stock to thread. Common sense makes it obvious that everything that invariably *is*, is essential and that all essentials are so because of a good reason; a progressive mind wants to know something of some of the whys and wherefores.

A general discussion of the merits and traits of the various thread standards is not within the scope of the present writing, but the dimensions of the four principal standards, for the range given in the Table XIII, as well as the bolt data, together with some general remarks on the subject are appropriate.

All pipe, valves, and fittings of regular stock used in North America, have threads that may be said to be universally interchangeable. This was not so true, especially with Canadian goods, until about 1880, when the adoption of the Briggs' Standard, for pipe and fittings, was secured through the work of a committee of the Society of Mechanical Engineers. The dimensions of the Briggs' Standard thread from $3\frac{1}{2}$ to 27

threads per inch of screw, are given, first, at the left, in the table; the Briggs' form is shown by Fig. 20, on which are given reference letters **A**, **B** and **C**; these also appear under Briggs' at the head of the columns

Table XIII. Thread Standards††

Number of Threads per Inch of Screw		Dimensions in inches									
		Briggs Pipe Standard Form			Sharp "V" Form	United States Standard Form			Whitworth Form		
*Pipe sizes	Bolt sizes	A	B	C	A	A	B	C	A	B	R
Brigg's	3½	.2286	.0094	.0109	.2474	.1856	.0309	.0357	.1830	.0457	.0392
	4	.2000	.0082	.0095	.2165	.1624	.0271	.0313	.1601	.0400	.0343
	4½	.1777	.0073	.0085	.1925	.1443	.0241	.0278	.1423	.0356	.0305
	5	.1600	.0066	.0076	.1732	.1299	.0217	.0250	.1281	.0320	.0275
	† 5½	.1454	.0060	.0069	.1575	.1181	.0197	.0227	.1164	.0291	.0250
	6	.1333	.0055	.0064	.1443	.1083	.0180	.0208	.1067	.0267	.0229
	7	.1143	.0047	.0054	.1237	.0928	.0155	.0179	.0915	.0229	.0196
8 (2½ up)		.1000	.0041	.0048	.1083	.0812	.0135	.0156	.0800	.0200	.0172
	9	.0888	.0037	.0042	.0962	.0722	.0120	.0139	.0712	.0178	.0153
	10	.0800	.0033	.0038	.0866	.0650	.0108	.0125	.0640	.0160	.0137
	11	.0727	.0030	.0035	.0787	.0591	.0098	.0114	.0582	.0146	.0125
11½ (1-in. up)		.0696	.0029	.0033	.0753	.0565	.0094	.0109	.0557	.0139	.0119
	12	.0667	.0028	.0032	.0722	.0541	.0090	.0104	.0534	.0133	.0114
	13	.0615	.0025	.0029	.0666	.0500	.0083	.0096	.0493	.0123	.0106
14 (¾ & ½)		.0571	.0024	.0027	.0619	.0464	.0077	.0089	.0457	.0114	.0098
	† 15	.0533	.0022	.0025	.0577	.0433	.0072	.0083	.0427	.0107	.0092
	16	.0500	.0021	.0024	.0541	.0406	.0068	.0078	.0400	.0100	.0086
	† 17	.0471	.0019	.0022	.0509	.0382	.0064	.0073	.0377	.0094	.0081
18 (⅜ & ¼)		.0444	.0018	.0021	.0481	.0361	.0060	.0069	.0356	.0089	.0076
	20	.0400	.0016	.0019	.0433	.0325	.0054	.0063	.0320	.0080	.0069
	† 22	.0364	.0015	.0017	.0394	.0295	.0049	.0057	.0291	.0073	.0062
	† 24	.0333	.0014	.0016	.0361	.0271	.0045	.0052	.0267	.0067	.0057
	† 25	.0320	.0013	.0015	.0346	.0260	.0043	.0050	.0256	.0064	.0055
	† 26	.0308	.0013	.0015	.0333	.0250	.0042	.0048	.0246	.0062	.0053
†27 (⅛)		.0296	.0012	.0014	.0321	.0241	.0040	.0046	.0237	.0059	.0051

U. S. Standard Bolts—Dimensions in Inches

Diameter of Bolt and of Tap for Threading	No. of Threads per Inch of Screw	Diameter of Hole for Tapping	Diameter of Drill Usually Used to Drill for Tapping	Cross-sectional Area—Root to Root of Thread	Lbs. Safe Tensile Strain with Safety Factor of 5, and Iron at 50000 per sq. in. Ultimate Strength	Distance Across Corners of Hex. Heads and Nuts
¼	20	0.1910	0.196	0.0286	286	37/64
5/16	18	.2403	0.246	.0452	452	11/16
⅜	16	.2938	0.297	.0677	677	51/64
7/16	14	.3447	23/64	.0932	932	29/32
½	13	.4001	13/32	.1257	1257	1 1/64
9/16	12	.4542	15/32	.1620	1620	1 ⅛
⅝	11	.5069	33/64	.2018	2018	1 15/64
¾	10	.6201	⅝	.3020	3020	1 29/64
⅞	9	.7307	47/64	.4194	4194	1 43/64
1	8	.8376	27/32	.5509	5539	1 ⅞
1⅛	7	.9394	61/64	.6930	6930	2 3/32
1¼	7	1.0644	1 5/64	.8890	8890	2 5/16
1⅜	6	1.1585	1 11/64	1.0540	10540	2 17/32
1½	6	1.2835	1 19/64	1.2930	12935	2 ¾
1¾	5	1.4902	1 33/64	1.7440	17441	3 3/16
2	4½	1.7113	1 23/32	2.3000	23000	3 39/64
2¼	4½	1.9613	1 31/32	3.0210	30214	4 3/64
2½	4	2.1752	2 3/16	3.7140	37149	4 31/64
2¾	4	2.4252	2 7/16	4.6180	46181	4 29/32
3	3½	2.6288	2 41/64	5.4279	54275	5 11/32

* Also used on bolts and rods of the diameters given in the bolt table herewith.
† Bolt sizes not given in the bolt table herewith.
††See illustrations of threads, conforming to the different standards, on page 70.

of the table over dimensions corresponding to those of the threads of the different pitches.

"Pitch" is the distance a thread travels axially along the stock in one revolution, that is, say, in the sharp "V", axially from apex to apex;

in the U. S. Standard, axially, from the beginning of one "flat" to the beginning of another. **C**, in the sketches, indicates the *flat*,—the actual thread of the Briggs' and **"V"** being rounded off. The "flats" in the sketches are exaggerated, and the 4-place decimals representing them in the table look formidable, but, actually, they are scarcely appreciable in *big* threads of the Brigg's Standard and are inappreciable in the sharp "V" (it is impossible to cut an absolutely sharp top thread)

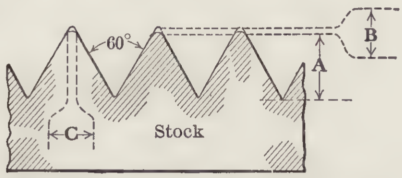


Fig. 20. Thread Standards—Briggs Standard Pipe Thread Form

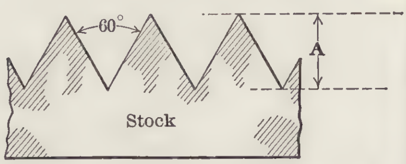


Fig. 21. Thread Standards—Sharp "V-Thread" Form

standard, but are *actual* and quite apparent in the U. S. Standard. In each case, **"A"** is the height of the thread; **B**, the extra height that would be added if the thread was instead, cut, for any pitch, to a sharp top, and **C** the width of the "flat," or, if a paradox allowable, the base if the *missing portion*.

The angle of the sides of the *trench* and *stock* of the Brigg's; sharp "V," and U. S. Standard threads is 60 deg. The Brigg's, like the other standards, is used for solid stock (rods and bolts) throughout the whole range.

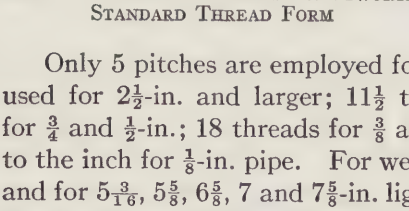


Fig. 22. Thread Standards—Whitworth Standard Thread Form

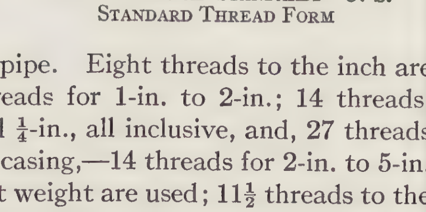


Fig. 23. Thread Standards—U. S. Standard Thread Form

Only 5 pitches are employed for pipe. Eight threads to the inch are used for $2\frac{1}{2}$-in. and larger; $11\frac{1}{2}$ threads for 1-in. to 2-in.; 14 threads, for $\frac{3}{4}$ and $\frac{1}{2}$-in.; 18 threads for $\frac{3}{8}$ and $\frac{1}{4}$-in., all inclusive, and, 27 threads to the inch for $\frac{1}{8}$-in. pipe. For well casing,—14 threads for 2-in. to 5-in. and for $5\frac{3}{16}$, $5\frac{5}{8}$, $6\frac{5}{8}$, 7 and $7\frac{5}{8}$-in. light weight are used; $11\frac{1}{2}$ threads to the inch for 5-in. and $5\frac{3}{16}$-in. heavy weight. Eleven and one-half threads to the inch are used for other sizes. Ten threads to the inch on 7-in. and 8 threads on $8\frac{5}{8}$-in. are also sometimes cut on heavy casing.

Each pitch is very well adapted to the sizes of pipe it is used on,—was, in fact, selected for that reason. Compared with pipe, the cross-section of material in rod form much exceeds that for pipe of like diameters. The tensile strength is as the material, and in solid stock the depth of thread is not limited, by limited thickness, as is the case with

pipe walls; hence, the use of heavier threads, than is used on pipe, for solid stock of equal diameters. For instance: the external diameter of $\frac{3}{4}$-in. pipe is 1.05; its "root" area, say .7349, and the thread used on it, 14 to the inch; the area of the outer diameter, less twice the height of the thread, minus the *actual* internal area equals .2016, the cross-sectional area of actual uncut material: in rod stock, 14 threads to the inch are used on $\frac{7}{16}$-in. diameter, having a "root" *diameter* of .3233,—say .082-in. cross-section area for the diameter, root to root of thread,—less than half that of the metal area for $\frac{3}{4}$-in. pipe, while the metal in the root area of $\frac{1}{2}$-in. pipe is .109,—only a little more than that of $\frac{7}{16}$-in. rod taking the root area. On the other hand, for like diameter,—the $\frac{3}{4}$-in. pipe, is 1.05-in.; 1-in. rod, of a little less diameter than $\frac{3}{4}$-in. pipe, takes 8 threads to the inch; $1\frac{1}{8}$-in. (1.125) takes 7 threads to the inch. Similarly, 2-in. pipe, the largest size $11\frac{1}{2}$ threads to the inch are used on, has a metal area of 1.074-in., approximately the area of $1\frac{1}{8}$-in. rod, on which 7 threads to the inch are used. Solid stock the same diameter as 2-in. pipe ($2\frac{3}{8}$-in.) takes $4\frac{1}{2}$ threads to the inch of screw. The relative metal areas are about 4 of rod metal to 1 of pipe metal for like diameters. It is seen by this that bolt threads need to be much heavier for like diameters, because of the extra metal they take care of the strain for, and that pipe threads, while necessarily limited in effective depth by the thickness of the pipe wall, are still roughly proportional to the metal area of some of the sizes they are used on.

The value of rod and bolt service lying usually in the tensile strength, their threads were largely determined by the factor of tensile strain. As pipe is not ordinarily subjected to heavy tensile strain, the threads employed were made to approximate the requirements of strength, with due respect to the thinness of pipe wall and to the making of tight joints thereon.

In emergency, or for special cases, a greater or less number of threads to the inch than standard may be cut on pipe (with lathe tools or special dies), as occasion may require, with good results, but the standard pitch is not varied merely on account of thickness of walls, as too many dies and taps would thus be needed,—standard, extra heavy and hydraulic pipe are all threaded with the same dies, yet the metal area varies materially.

The sharp "V" thread is a little higher, and sharper than the Brigg's Standard, but the angle of the sides is the same. It is shown in Fig. 21.

The Whitworth Standard, shown in Fig. 22, a bolt thread used extensively in England since 1841, has also been largely used across the water for pipe threading. For common water and gas pipe, the Whitworth threads used are: for $\frac{1}{8}$-in., 28 threads to the inch; for $\frac{1}{4}$ and $\frac{3}{8}$, 19; for $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$ and $\frac{7}{8}$, 14; and, for larger than $\frac{7}{8}$-in., 11 threads to the inch. For hydraulic piping the threads, by the same standard, for external

diameters $\frac{5}{8}$-in. to $1\frac{1}{8}$-in., are 14 threads, and for other, larger diameters, 11 threads to the inch. The Whitworth Standard is characterized by its angle including but 55 deg. and by the arc top and bottom. The radius of the arc **RR** is given under **R** in the table.

In Fig. 23 is illustrated the *U. S.* Standard thread (William Sellers form adopted about 1865); it varies from the Brigg's in its decided flat top and bottom. Otherwise there is little more than has been said to say about it, as all of the dimensions are given in the table. It should be remembered that the sketches are exaggerated and that the basis for close comparison is therefore in the table measurements. No question of relative merits of the standards need be raised here.

Appended to the table of thread dimensions is another, giving the principal data concerning bolts of from $\frac{1}{4}$-in. to 3-in. diameter, according with the U. S. Standard. The threads per inch, heads, nuts, diameters and safe loads are, so far as the trade's needs go, practically the same for the other standards, and will serve as a guide in fixing the size of odd bolts, rods and pipe (pipe proportioned by the area of metal contained), where tensile strains on pipe or solid stock are to be provided for.

The size of drill hole, and the nearest regular size drill generally used for drilling for the tap are given. If the depth of any U. S. thread not given is wanted, multiply the pitch by 0.65; thus for depth of thread at 5 threads to the inch: 0.20 = pitch and .20×.65 = .1300,—given in table as 0.1299, and within $\frac{1}{10000}$ of correct. The width of flat is equal to $\frac{1}{8}$ of the pitch. To get the usual size drill for the tapping-hole for any size, divide 1.299 by the number of threads to the inch, and subtract the quotient so obtained from the diameter of the tap and then take the nearest larger regular size drill as proper. For ordinary sizes, the drill should be within $\frac{1}{64}$ of the figured size: Thus, for drilling for a $\frac{3}{4}$-in. tap: $\frac{3}{4}$ takes 10 threads per inch; 1.299÷10 = 0.1299, and 0.7500—0.1299 = 0.6201, the exact size of the hole as given in the table; a $\frac{5}{8}$-in. drill equals 0.625-in. diameter, so a $\frac{5}{8}$-in. diameter drill is the size to use, as given in the bolt table.

To find the drill size for "V" Sharp threads, proceed as just directed for the U. S. Standard, *after* substituting 1.733 for the U. S. divided "1.299" used in previous sentence,—that is, divide 1.733 by the number of threads per inch and subtract the quotient from the bolt diameter; for bolt sizes of the Brigg's Standard, the tapping drill is found in the same way by substituting 1.6 for the U. S. dividend "1.299" and proceeding as above directed. For the drill for pipe sizes it is easiest to deduct twice the depth of the thread to be used from the standard diameter of the pipe to be drilled for.

By juggling the data in the two tables of Table XIII the reader can himself develop such special helps as he may need, with reference to threads of other standards.

CHAPTER XIV

Imperfect Threads and Their Causes

With a good make of dies in perfect condition, properly set, good oil, (Lard oil) and wrought iron pipe, a novice would have only himself to blame if he did not cut good threads, in moderate weather, without injury to the dies or pipe, provided the vise that held the pipe was good, that he "blew out" the chips if they stacked up in the clearance spaces, and, put sufficient oil in the right place at the right time. This array of provisos indicates that many things must happen to be "right" before an unskilled person is likely to cut a good thread; they equally imply that much greater skill is required to get good results on the average than is ordinarily believed to be necessary. All of the features mentioned are, in practice, seldom to the liking of a proficient workman, and if the pipe, dies, oil or vise is poor, he must contrive to offset the deficiency with skill. If two or more essentials are not up to par, human skill and patience are sometimes inadequate and the result is poor in spite of all efforts.

The importance of some defects is, however, overestimated, though there are others that are frequently undervalued. If due need of attention was always given this kind of work by apprentices and the journeymen under whom they work, there would be much less complaint concerning threads, both as to tools and materials. Some elements of the subject have doubtless been entirely overlooked, by the younger members of the trade especially. What follows should pave the way to success over any obstacle ordinarily contended with.

In Fig. 25 is shown in the pipe section, a defect too often met with, not only in plumbing shop work, but in factory cut nipples, and sometimes in the work of "pipe-cut-to-order" shops; it is the round, "filled," "Whitworth" bottom resulting either from dull or worn out dies. The apex of die teeth often break off from hardness or misuse, or wear back,—generally the latter. In this condition they "ride" the metal at the root of the thread instead of removing it. Dies in which the ridge of the teeth have worn down to a Whitworth top, all the way back to the clearance flats, produce the same result, but they are worthless,—worn out. All taps, and all "piece" dies having still a portion of full-height teeth between the relief flats and the cutting edges can easily be reground on an emery wheel or a good grindstone. Solid dies can sometimes be whetted or filed sharp. The small sketches, at right in Fig. 25, show a fragment of die and the cross-section of a tap, indicating cutting edges and the direction in which they should be ground, by means of

arrows and the dotted lines **Z**, and **XY**. If too much rake is given the teeth they will "dig in" and are likely to break.

A section of worn die or tap thread is shown at **J**, Fig. 26. The fitting thread in Fig. 26 shows a round bottom like illustrated on the pipe thread in Fig. 25. It is rare that this trouble is found to a marked

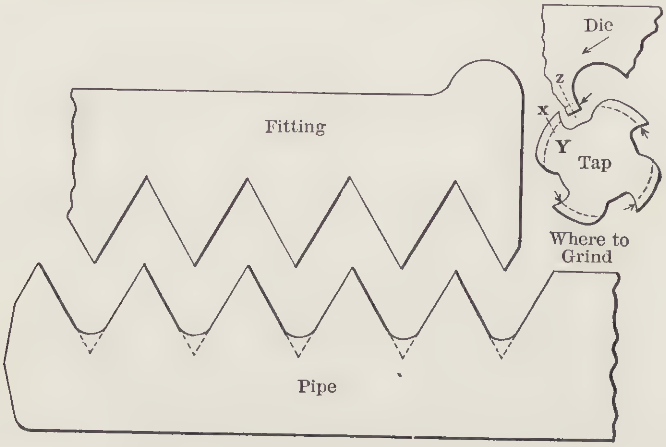


FIG. 25. THREAD DEFECT FROM DULL DIES

degree in fittings. The round bottom is a most aggravating defect—though its use is imperative on some occasions—necessitating the filling flat of the first threads to get a safe hold, and then forcing to make a shoulder thread or two cut or mash their way into more or less intimate contact.

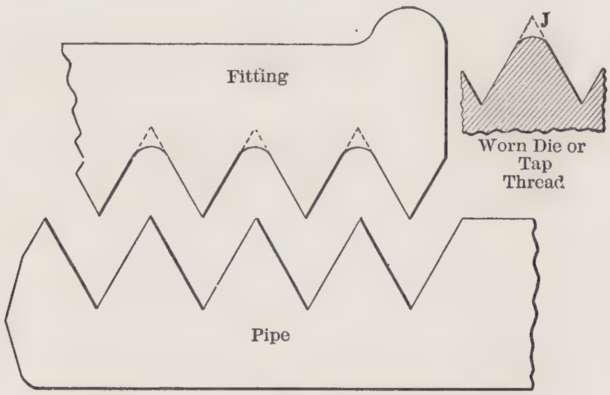


FIG. 26. THREAD DEFECT FROM DULL TAPS

Fig. 27 represents, in section, a defect prevalent in both pipe and fittings of competition goods,—the flat top as marked by **bbb**. On pipe, this is due to the outside diameter being less than standard; in fittings it is the result of the hole tapped being too large,—greater than

the standard diameter from root to root of the pipe thread. This may be due to shrinkage, core fault, or what not, but is not one of the premeditated scrimpings that characterize cheap product. Care is taken by all good makers to cull out, as nearly as possible all articles bearing the fault.

If the diameter of the pipe is deficient for the whole length of the portion to be threaded (a practiced eye can generally tell at a glance on small sizes, up to 1-in., without measuring) it is best to cut the pipe with a cutter that leaves the burr outside, so as to get one *full thread* on the end when the dies are applied. This is the only reasonable way to get a tight joint (metal to metal) without calking or "shutting up" the starting thread of the fitting after the joint is screwed up, because such flats often form a triangular spiral void leading all the way from the interior to the outside, at the shoulder.

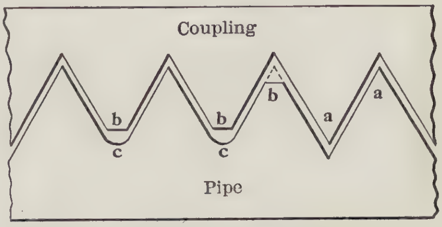


FIG. 27. COMBINED DEFECTS OF DULL DIES AND DEFICIENCY IN PIPE AND FITTING STOCK

Of course, hemp, jute or candlewick, soaked in oil or paint, can be wrapped in the thread to fill, or at least so it will trap a pigment enough for the pressure to compact it to water-tightness; or, some paste (red lead, white lead, litharge, or graphite in oil with dryer, or in shellac varnish) that will dry tight can be used. The latter remedies must be resorted to in the case of fittings, unless it is handy to tap the fitting *oversize*, by hand, deep enough to get sharp tops, and then cut an *oversize* thread on the pipe to match,—which will sometimes make conditions equally as bad by leaving flats on the pipe thread.

Ordinary pipe taps generally run so deep as to butt the back of elbows before enlarging the hole. If flats on both fitting and pipe threads happen to come together throughout, the avenue for leakage is doubled, but closing the starting thread by pinching it to the pipe metal with a delicate calking tool (a rather dull cape chisel) will stop or prevent leakage. Round bottom threads will screw into flat tops, as at **b**, **c**, Fig. 27, easily, and sometimes by chance make tight. In this way, also, by selection, two defects can now and then be made to neutralize each other. Threads *should* be full as at **aa**. The parts are drawn separated in the sketches, to avoid confusion in references.

Fig. 28 illustrates a number of defects that may occur through faults of workmanship or tools, or that may be due to imperfections of material. At **d** and **e**, a portion of the thread is stripped to the root. This may be due to the pipe being what is called mild steel, which has the trait of stripping at about thread depth,—probably due to varying

hardness, the harder metal being at the surface and requiring so much power to remove the thread cuts, with some forms of dies, as to shear the thread portion from the softer metal below, at the root of the thread.

Chips in the die clearance spaces is the chief cause of thread stripping. Considerable of an otherwise good thread may be broken out in this way at one place or in fragmentary patches at different places, without impairing the value of the thread to an appreciable extent. A very little of a perfect and clean thread screwed into intimate contact, at any point, with a clean perfect thread will hold any ordinary pressure indefinitely, if the parts are protected from corrosion by oil, graphite or some good pipe joint compound. Threads practically without blemish, that is, such as can be made with good dies, and taps, can in the $\frac{1}{2}$-in. pipe size, if well oiled be screwed together by hand, so they will retain 1000 lbs. pressure. This statement is not to be taken as license for careless work; it merely shows the value of *clean, lubricated*, metal-to-metal surface with reference to joint-tightness.

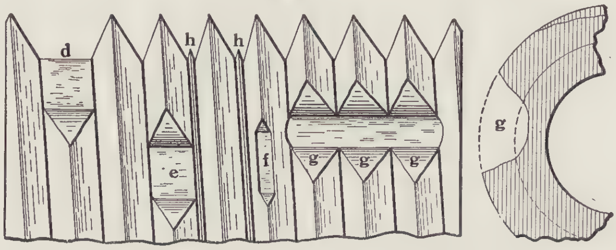


FIG. 28. DEFECTS OF POOR WORKMANSHIP AND MATERIAL

Average conditions of practice are vastly different from what can be made to prevail in particular instances, through skill and selection. The author believes in cutting threads full length (to suit the thread depth of whatever they work into) and screwing them into place "*tight*." Some judgment must be used as to what constitutes "tight." It should always be far short of straining the pipe to the extent of injury; then too, what is "tight" on one size is "loose" on another; "tight" by the degree of "pull" with one and the same wrench or tongs will be *right* for one size, too "tight" for a smaller and too "loose" for a larger. Governing the "tightness" by an arbitrary individual standard "pull" and changing leverage (length of wrench) to suit the more or less power required, according to size, will not alone answer, unless the handle of the same or same kind of wrench is extended to give the same "pull"; even if this precaution is taken as a guide, by using a sliding pipe on an iron handle wrench, its safeness is limited, because for the larger sizes a wrench can be used with, the back and traveling-jaw surface is not enough (out of proportion to the possible power applicable through the extended handle) to keep the jaw from biting into the metal to an

injurious degree. Therefore, the jaw surface must be proportional to the work. It is frequently wise to use two similar wrenches to screw up with, with the jaws set quartering on the pipe (handles separated 90 deg.). In this way, the tendency of one wrench, under strain, to change the form of the pipe in one diameter from circular to elliptical major axis is counteracted by the other wrench endeavoring to alter the same diameter to elliptical minor axis; thus the pipe is kept round, if the "pull" on the wrenches is at all equal. The weld of the pipe should, if convenient, always divide either the angle between the wrench handles, or in any event one of the other quadrant of the circumference indicated by handles. In this position there is less danger of cracking the weld.

It will be inferred from what has been said that, as before stated, defects **d** and **e**, and their incipient companion, **f**, Fig. 28, are usually overrated in importance, so far as tight joints are concerned. This is also true in a large measure, as regards tensile and torsional strain The prime mission of pipe is to convey the contents, and outside of tall building work, which requires more than ordinary care in fitting with a view to taking care of tensile strain on risers, the shearing surface of pipe threads gives a high factor of safety against any strain normal to service. So, while it is true that any tearing of the threads weakens the resistance of the joint to pulling strains, it is also true that a reasonable amount of thread may be stripped without incurring any danger of it pulling out from internal pressure or from any strain a pipe joint ought to stand during fitting or while in normal service.

The hollow indicated by **gg** will cause leakage if it extends the whole length of the thread and is deep enough to reach below the root of the threads, as shown in Fig. 28 and more distinctly by **g** in the cross-section at the side. The same is true of a fitting thread,—a mere ditch in the threads, and not reaching the root depth will not leak.

At **h**, **h**, Fig. 28, a diminutive thread is shown between the spirals of the other. This effect varies from a slight *width* at bottom to two threads (double the number to the inch) of half the proper size, and may be caused by "piece" dies not being mates, or from mates not set in proper alignment. Dirt, or chips of greater or less size, on the bed of the die-plate on one side, or unevenly distributed over both sides keep the dies from seating properly. Die pieces must be held in the stock in the same relative position they occupied in the piece, in the chuck or holder at the time the threads in the dies themselves were cut; otherwise true threads cannot be cut. The die maker has provided guides and seats in the stock to hold the dies in the right position, and it is to the interest of everybody concerned that they be always so set. The remedy for thread doubling is: when setting, place clean dies in a clean stock.

To put up tight satisfactory work requires eternal vigilance to avoid split pipe, filled pipe, cracked fittings, sand-holes in fittings, low flats,

creases and ditches, to say nothing of other points requiring care and skill. One therefore need not hope to be on guard beforehand regularly enough to practically always foresee and prevent trouble, without experiencing a reasonable number of failures and disappointments, no matter how hard he may try; but, the beginner can easily watch the more prominent causes of trouble.

Die clearances are less in the larger sizes of all forms, and have to be watched closer. The chips must be blown out before they pack enough to tear the thread; oil should be put on, in different clearances, more than once, during the cutting of an ordinary thread,—and put on the thread, too, not on chips; oil not only lubricates, but cools the pipe and dies. By "feeling" for it, a certain vibration in the die-stock handles can be felt before tearing from chips has done too much damage to be corrected by the dies in the finishing of the thread,—it is generally too late to remedy after the ear hears the sound that betrays stripping from friction of the dies or abrasion by chips. If a solid die is thick, and has so much friction surface as to twist the pipe unless great care is exercised, knock out some of the front teeth in each quadrant,—the die will wear out quicker, but it will be money saved; if the piece dies are thick and give trouble for the same reason when cutting a full thread at one cut, grind away two or three of the front teeth of each; when dies get dull, grind them,—if they can not be sharpened, get new ones that can.

Good tools require good treatment to get their worth of service out of them,—keep them in good order, and clean. Never put oil on an end until the thread is started, unless the pipe is small; put chalk on the pipe end if the dies do not take hold; get the habit of pulling the stock handles through one and the same plane,—do the same thing when starting a thread,—twisting the die over the pipe "chews" the pipe metal way and may break off the starting threads of the die as well as of the thread being started on the pipe. Use only the sizes of pipe intended by the maker, in a pipe vise,—in order to reduce the dimensions of pipe vises, the jaws are made too obtuse to hold small pipe without mashing it. Never try to cut threads when the dies and pipe are both very cold,—one will surely *strip* and the other is most certain to break out more or less. Oversize threads are possible to a slight degree in very severe weather if the die is solid and the pipe cold; undersize may result from threading pipe that has been laying in the sun, with hot dies,—hot from work or from also laying in the sun. Try some of the fittings to be used, on pipe of the same temperature, if they show a tendency to under or oversize, cut the threads accordingly.

CHAPTER XV

Pipe Fittings

Staple pipe fittings are so generally known that little need be said of them. The ordinary kind are of short (about 1 diameter) radius, have bore suitable for tapping and will stand any pressure likely for plumbing service. Malleable fittings are used, as a rule, up to 3-in.,—black, generally, for gas, and galvanized for water. Plain end galvanized fittings have come to be more used than formerly for gas,—they have no sand holes, and save the extra cost in testing.

Malleable fittings are made with plain ends, banded, and beaded ends,—the beaded and banded galvanized being regular for water work.

When friction is allowed for, 40 diameters for 90 deg. ells, 60 for tees and 20 for couplings are reckoned for each; that is, the delivery pipe is assumed to be that many diameters longer, for each of the respective fittings when calculating the friction loss for the line. Sixty diameters are allowed for a common globe valve. Long radius fittings reducing friction, due to change of course, to a minimum are made in all requisite sizes.

The fittings of different makers approximate each other very closely. The makers have a list of "Standard" black and galvanized which are furnished as "regular,"—other fittings being termed "special," may cost more, and usually cause delay on account of not being in stock. The Standard list varies slightly with different makers. All makes of ordinary fittings are sold by "piece list" and by the pound, the "pound list" being classified fittings graded in price per pound to equal the difference in cost of molding and tapping the smaller sizes.

Besides the ordinary malleable fittings made in: 90 deg. female and male and female ells; 45 deg. female and male and female ells; tees, female and male and female; wing tees; wing ells; 3-way ells; 4-way ells; lock-nuts; waste-nuts; couplings, plugs; caps; bushings; Ys, crosses and return bends, there are also made:—

For wrought drainage work: a full line of cast fittings with recessed ends are made. The body of these fittings have the same bore as the pipe tapped for. The bends are made in $5\frac{5}{8}$ deg., $11\frac{1}{4}$ deg., $22\frac{1}{2}$ deg., 30 deg., 45 deg., 60 deg., and 90 deg. There are also many specials in this line, including "pitched" ells and tees, so tapped (to rise or fall about 1 deg. per foot of "run") to afford proper fall in the laterals and yet maintain vertical lines,—without the fitter having to cut "crooked" threads.

For use with Iron Pipe size brass pipe: a full line of brass fittings,

rough, polished, and polished and nickel-plated, are made from beaded malleable pipe fitting patterns, and tapped iron pipe thread.

For heavy pressures, car heating and air work: a line of extra heavy cast threaded fittings are made.

For steam work, especially in large sizes, a line of "Standard" and "Extra Heavy" cast iron and steel flanged fittings, joined by bolts and gasket are made.

For ammonia work, a suitable line is made, threaded, with recessed ends, furnished with threaded follower gland to enter the recess and having the same function and action as the lock-nut or half-couplings on common long-screws. These fittings are also furnished with the gland bolted up,—the bolts being held by lugs cast on the fittings.

For oil, gas and salt well work, a full line of "casing" fittings are made,—being tapped with well-casting threads.

For hand rails, fence work, awnings, etc., a full line are made in malleable iron and brass from suitable patterns, tapped regular Iron Pipe thread. This line includes wall attaching pieces, gate hinge fittings, finials, and Ys and bends of special types.

Besides the above, there are "cross-overs," "boiler fittings," union ells, and tees, wash tray fittings, etc., all once considered "special,"—now very generally handled as staples.

A union fitting always serves as a fitting, a nipple and a union and sometimes more. For this reason there was for a long time no inclination to market them at a price in keeping with staple fittings.

Table XIV gives the approximate weights of regular black malleable water fittings of the kinds that are sold by the pound. Every fitter knows it will not do to rely absolutely upon such weights, nor can one expect bills for fitting to tally. Such weights are nevertheless of great help in estimating. Those given in the table are the weights of one fitting of each size and kind, in decimals of a pound, being in each case one-hundredth of the weight of 100 fittings, all of the same make. Moving the decimal point one figure to the right will give the weight of 10 fittings, two places to the right, that of 100 fittings,—instead of one.

Some peculiar facts develop in weighing up fittings:—A few reducing sizes weigh more than the straight sizes. This is partly due to type of pattern and partly to the length of body required by the branch. Also, in some degree to the relative weights of metal in the branch nipple and the relation this metal would bear to that necessary to complete the body into a cylinder,—change the branch-hole into wall. For variation in weights of the fittings and for margin in the estimation of number needed it is safe for estimating purposes to add at least $\frac{1}{10}$ to the aggregate weight required.

For galvanized fitting weights add *10 per cent.* to the weight of black. As different makes may vary more or less, a few fittings of

Table XIV. Malleable Pipe Fittings—Weight Each in Decimals of a Pound. Move Point One Place to Right for Weight of 10 and Two Places for 100 Fittings

Kinds | Sizes	⅛ in.	¼ in.	⅜ in.	½ in.	¾ in.	1 in.	1¼ in.	1½ in.	2 in.	2½ in.	3 in.
Ells	.06	.12	.185	.28	.415	.685	1.02	1.37	2.2	3.80	4.60
Ells, red, one size	....	.09	.155	.25	.39	.615	.88	1.37	1.77	3.80	5.46
Ells, red, two sizes	....	....	.15	.25	.42	.60	.94	1.16	1.96	2.75	4.60
Ells, red, three sizes	....	....	....	....	....	.52	.80	1.26	1.83	....	4.90
Ells, M. & F.	....	.11	.18	.295	.535	.655	1.10	1.60	2.6	4.5	6.3
Ells, M. & F., red, one size	....	....	....	....	.42	.585	.94	1.44	2.16	....	....
Ells 45 deg. F.&M.&F.	....	.13	.16	.255	.36	.55	.92	1.24	1.75	3.17	5.63
Ells, 3-way	....	....	.17	.30	.33	.55	1.2	1.5	2.0	....	....
Ells, 3-wayred, one size	....	....	.14	.24	.30	.48	1.1	....	....	....	....
Ells,3-wayred,twosizes	....	....	....	....	.29	.51	....	....	....	....	....
Ells, wing	....	.16	.22	.33	.36	.535	....	....	....	....	....
Tees	.095	.12	.19	.31	.565	.82	1.32	1.6	2.7	4.76	9.0
Tees service	....	....	....	....	.48	.94	1.36	1.9	3.0	....	....
Tees, 4-way	....	....	.25	.29	.40	.99	1.32	1.54	....	....	....
Tees, wing	....	....	.215	.275	.56	.83	....	....	....	....	....
Tees, red, one size	....	.10	.175	.26	.49	.75	1.11	1.6	2.23	3.54	6.4
Tees, red, two sizes	....	....	.123	.24	.43	.64	1.09	1.37	2.0	3.05	6.0
Tees, red, three sizes	....	....	....	....	.46	.65	.86	1.18	1.87	3.0	5.25
Nuts, lock	.027	.035	.06	.07	.13	.175	.26	.34	.50	1.85	2.0
Nuts, waste	....	.05	.07	.10	.10	.15	....	....	....	....	....
Couplings	.06	.072	.14	.20	.29	.53	.77	1.11	1.67	....	....
Couplings, red, one size	....	.06	.12	.15	.23	.415	.52	.66	1.08	1.88	3.0
Couplings,red,twosizes	....	....	.085	.14	.21	.32	.43	.68	.95	1.75	2.6
Plugs	....	.04	.07	.09	.13	.275	.46	.585	.94	....	....
Caps	....	.055	.075	.15	.21	.35	.585	.64	1.12	1.85	2.75
Crosses	....	.155	.245	.32	.64	.95	.148	2.0	2.9	6.0	8.2
Crosses, Br'nch's red, one size	....	....	.23	.28	.54	.76	1.36	1.84	2.65	3.75	6.57
Crosses, Br'nch's red, two sizes	....	....	....	.27	.49	.68	1.20	1.44	2.50	3.40	6.20
Crosses, br'nch's red, three sizes	....	....	....	....	.51	.68	1.04	1.28	2.32	3.28	5.15
Y's	....	....	....	.50	.81	1.17	1.98	2.82	4.4	6.35	10.9
Y's, red, one size	....	....	....	....	....	....	....	2.3	3.8	5.7	9.2
Ret. bends, open	....	.21	.22	.44	.83	1.04	2.0	3.1	5.5	7.1	10.5
Ret. bends, medium	....	....	....	.34	.60	.92	1.6	2.55	3.37	....	....
Ret. bends, close	....	.155	.22	.35	.71	1.0	1.68	2.44	3.88	6.31	8.80
Kinds | Sizes	⅛ in.	¼ in.	⅜ in.	½ in.	¾ in.	1 in.	1¼ in.	1½ in.	2 in.	2½ in.	3 in.

different sizes should be weighed by every user of the table in order to see how the weights of the fittings in stock compare with those in the table

In ordering or naming fittings it is the rule to name the "run" first, then the branch or branches. Only two ends are ordinarily named either for tees or crosses unless the "run" openings are of different sizes: three or four ends may then be named in the order stated according as the order is for tees or crosses, and if for crosses, whether the "run" and "branch-run" both have unequal ends.

The plumber uses malleable fittings more than any other kind. These are, to begin with, merely cast iron; as offered in the market the carbon has been more or less removed by keeping them red hot for several days in a close retort in contact with oxide of iron which removes the carbon from the iron through the oxygen of the oxide combining with it. Steel can be made of wrought iron in much the same way as malleable is made of cast iron, though the process is the exact reverse with reference to the movement of the carbon,—the iron is packed closed, with charcoal and heated until it absorbs 1 to $1\frac{1}{2}$ per cent. of its weight in carbon from the charcoal, or, it is placed in crucibles in contact with charcoal and melted to accomplish the same result quicker.

Every one is familiar with the ordinary blacksmith's case hardening of articles by packing and heating them in contact with leather scraps, hoof parings, etc.,—steel making from iron as named, is practically the same process on a large scale.

Eccentric tees, bushings and couplings are made. These are almost necessary in some heating and drainage positions.

Iron bushing sizes, reducing one size, are malleable with circumscribing hexagon; those reducing two or more sizes are generally cast, and are made in both circumscribed and inscribed hexagon styles.

An eccentric "bushing" or coupling can be made by drilling and tapping a cap. For emergency work a coupling may be tapped to make a tee, or a tee tapped to produce a cross.

Two pipe ends, or one and an article, both stiff (fixed) require a union fitting. These are made in the form of two threaded flanges bolted together with gasket between, and in various types of 3-piece unions having a collar that pulls on a shoulder on the spud and screws right handed over the other part, inclosing, (surrounded by the collar, if not of the ground-face style) a gasket between the faces of the main parts. Common unions have a lip on the spud at the bore, which extends into the other part; this holds the gasket in alignment preliminary to screwing up the collar. The lines must have end-play enough to *enter* the lip. There is also made a 3-piece union with jogged lip-less faces, having a right-handed thread in the coupling (equivalent to the colla

common unions) and on the spud and its companion piece. No end-play of the lines is required for this union and the collar screwing over tapered threads, cut on both pieces as one, the *union* joint is the same as an ordinary pipe thread point.

Right and left threads are also used to join stiff ends, mostly where the connection is not often broken,—as in heating work. These require the end-play of two thread lengths; the threads must be tried and counted in order to give one sufficient lead (if they do not make tight in an equal number of revolutions) to cause both to "make tight" at the same time. Twice the power is required to screw up both threads at once as would be for one. Ribs are cast on left ends of ells to identify them, and on couplings to distinguish them and to give the wrench an advantageous hold. Right and left nipples are equal to unions. For drawing up outside there must be room for a wrench between the threads, —room for two wrenches, preferably, as the force needed is great and the shortness of the piece causes it to crush easier than long pieces of the same size pipe. Close right and left nipples, as for radiator loop work, where the tightness of the joint depends on a gasket between the surfaces of the pieces drawn together instead of on the *threads*, generally have lugs on the inner surface. Short right and left nipples with exterior hexagon center are made. Right and left and right hand black and galvanized nipples in all lengths up to 6-in. are regular,—greater lengths are special.

Nipples of "casing weight" with *casing threads* can also be had. "Long screws" are used for joining stiff ends of pipe, tank attachments,—etc. For pipe use, a coupling and a half-coupling or lock-nut are used with the thread. Cored center couplings will not answer,—they must be threaded all through. The shoulder end of the coupling should be beveled inward and the packing end of the half-coupling or lock-nut likewise countersunk. This gives a cavity to hold lamp-wick, hemp or oakum soaked in oil or red lead and oil, and when backing up the lock-nut or half-coupling the bevels converge the packing so as to make a reliable joint.

Return bends are made both in cast and malleable iron, and in open, (center to center of pipe openings) medium open, close and extra close patterns; some sizes can be had with *back* or *side* opening.

For use where casing and regular pipe are both necessary in the same job, fittings are made having some of the openings tapped with "casing" and others with "pipe" thread.

When there is occasion to drill and tap with pipe threads, the size drills to use are: For $\frac{1}{8}$-in. use a $\frac{21}{64}$ drill; for $\frac{1}{4}$-in. $\frac{29}{64}$; $\frac{3}{8}$, $\frac{19}{32}$; $\frac{1}{2}$, $\frac{23}{32}$; $\frac{3}{4}$, $\frac{15}{16}$; 1-in, $1\frac{3}{16}$; $1\frac{1}{4}$, $1\frac{15}{32}$; $1\frac{1}{2}$, $1\frac{23}{32}$; 2-in., $2\frac{3}{16}$; $2\frac{1}{2}$, $2\frac{11}{16}$; and for 3-in., $3\frac{5}{16}$.

CHAPTER XVI

Wrought-Pipe and Well-Casing

Wrought iron and mild steel pipe are made in all sizes from $\frac{1}{8}$-in. to 12-in. nominal inside diameter, and larger,—over 12-in. being generally sold as O.D. (outside diameter) pipe. One and one-quarter-inch and smaller sizes are usually butt-welded; $1\frac{1}{2}$-in. and larger are always lap-welded, if welded at all,—seamless pipe has been made to a limited extent. Pipe is called by nominal sizes of *inside diameter*. The actual inside diameter of standard or Merchants' pipe is always larger than the *nominal* size,—this is why the word approximate is not used instead; other weights of pipe are equal to, or of less internal diameter than the nominal sizes, according to the extra thickness of wall over standard, which in all cases reduces the internal instead of external diameter.

Wrought iron pipe is a little rougher than steel and protective coatings therefore adhere better; it is softer; is uniform in its softness; can be threaded with less energy, with any type of dies; can be threaded with dies that have sufficient cutting surface to do good service much longer than any type of die that will successfully thread steel pipe; can be threaded without danger of twisting the weld or stripping the threads off; the weld is good at all points; and, without doubt, wrought pipe does in most situations last longer than steel. One of the best evidences of the superior merit and advantages of wrought-iron pipe for general purposes is that low carbon steel pipe, if not boldly sold as wrought iron, has been generally catalogued and sold as "wrought" pipe.

The average market steel pipe often cracks in the weld when cutting off or threading; strips the thread more or less when being threaded; frequently has a defective weld for which "the measure of damage is replacing the defective piece" into your hands at the store, if you are willing to incur the further loss of so getting it; is harder than iron, not uniformly hard, and is more expensive to install both from loss of time and because the dies suitable to cut it wear very quick. There is no disposition to here broadly discriminate against steel; it has merit enough to make a market on its merit; is highly efficient in some work, especially in dry locations where there is not much cutting. When galvanized, as for water uses, it will answer anywhere and the cutting is not quite so troublesome. The coating on steel pipe, however, is lighter than on wrought pipe and under corrosive action will "eat" through in spots correspondingly quicker.

It is only fair to say that there is but one kind of work on which the author would positively refuse to employ steel pipe and that is for

driving purposes. The threading will not stand drive-well strains. If a plumber is working to specifications, or voluntarily elects to raise the factor of cost of tool equipment and maintenance because he thinks he can save more in the other direction, which is possible, let him. The trade has less to complain of, as to steel pipe, now than formerly and it will perhaps come to a point where individual preference or general well defined superiority of one and the other in certain service will be the factors governing selection of the two materials as pipe.

Of course nobody could deceive a workman as to whether a pipe is of one material or the other, after he has once applied the dies, but now and then an owner or architect demands to be shown in a way that is conclusive to himself. If occasion calls for such demonstration, take a short piece of the pipe, unthreaded, file the cutter marks off the ends, (make the ends smooth as possible) and suspend (not lay in) two or three hours in an acid solution in a glass or porcelain dish or tray (a soup bowl will do). The solution or acid mixture should consist of 70 per cent. water, 22 per cent. sulphuric acid, and 8 per cent. muria ic acid. Add the muriatic acid last. Considerable heat will be evolved when the sulphuric is poured into the water, and some diminution of volume will take place, of which no notice be taken,—the proportions, practically 9 of water, 3 of sulphuric and 1 of muriatic acid before mixing are sufficient. After pickeling the pipe in the mixture as stated, steel pipe will have bright smooth unmarked ends unless there happens to be a bubble crack line; wrought-iron pipe will show slight, distinguishable ridges running *with* the wall of the pipe,—these markings are a characteristic of wrought-iron sheets and therefore of the pipe made from them. They are caused by a small percentage of the cinder taken up in the puddling furnaces, not eradicated by other subsequent operations, and which the presence of is considered an advantage. Cinder in wrought product is said to be due to resolidifying of the iron in the furnace. It is a fact that the purer an iron the higher its fusing point, and as particles of pig-iron become refined in the furnace, they, though fused as pig product, again solidify because the temperature of the iron in which they are swimming is too low for a time to hold them in the liquid state.

The reference value of pipe and well-casing data in a table of corelated dimensions, areas, etc., of standard and extra strong wrought pipe and well-casing, such as given in Table XV, is of inestimable value to the general mechanic. The data given in it cannot be found generally in any three books combined; without tabulation it is in fragmentary form; some not ordinarily available at all, and the whole of that within reach of even a methodical tradesman, so widely separated as to make quick comparisons by mere inspection out of the question.

At the top of the table are nominal pipe sizes (always a little less

Table XV. Wrought Pipe and Well-Casing Dimensions, Areas, Capacities, Etc.

Nominal pipe Sizes, inches	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4	$4\frac{1}{2}$	5	6	7	8
External diameters	.405	.54	.675	.84	1.05	1.315	1.66	1.9	2.375	2.875	3.5	4.	4.5	5.	5.563	6.625	7.625	8.625
Internal diameters	.27	.364	.494	.623	.824	1.048	1.38	1.611	2.067	2.468	3.067	3.548	4.026	4.508	5.045	6.065	7.023	7.982
	* **.205**	**.294**	**.421**	**.542**	**.736**	**.951**	**1.272**	**1.494**	**1.933**	**2.315**	**2.892**	**3.358**	**3.818**	**4.28**	**4.813**	**5.75**	**6.625**	**7.625**
Thickness of wall	.068	.088	.091	.109	.113	.134	.14	.145	.154	.204	.217	.226	.237	.246	.259	.28	.301	.322
	* **.1**	**.123**	**.127**	**.149**	**.157**	**.182**	**.194**	**.203**	**.221**	**.28**	**.304**	**.321**	**.341**	**.360**	**.375**	**.437**	**.50**	**.50**
External circumference	1.272	1.696	2.121	2.639	3.299	4.131	5.215	5.969	7.461	9.032	10.996	12.566	14.137	15.708	17.477	20.813	23.955	27.096
Internal circumference	.848	1.144	1.552	1.957	2.589	3.292	4.335	5.061	6.494	7.753	9.636	11.146	12.648	14.162	15.849	19.054	22.063	25.076
	* **.644**	**.924**	**1.323**	**1.703**	**2.312**	**2.988**	**3.996**	**4.694**	**6.073**	**7.273**	**9.085**	**10.549**	**11.995**	**13.43**	**15.12**	**18.064**	**20.813**	**23.954**
Area external diameters	.129	.229	.358	.554	.866	1.358	2.164	2.835	4.43	6.492	9.621	12.566	15.904	19.635	24.306	34.472	45.664	58.426
Areas internal diameters	.0573	.1041	.1917	.3048	.5333	.8626	1.496	2.038	3.356	4.784	7.388	9.887	12.73	15.961	19.99	28.888	38.738	50.04
	* **.033**	**.068**	**.139**	**.231**	**.452**	**.71**	**1.271**	**1.753**	**2.935**	**4.209**	**6.569**	**8.856**	**11.449**	**14.37**	**18.193**	**25.967**	**34.47**	**45.66**
Lin. ft. per sq. ft. external surface	9.44	7.075	5.657	4.547	3.637	2.904	2.301	2.01	1.608	1.328	1.091	.955	.849	.764	.687	.577	.501	.443
Lin. ft. per sq. ft. internal surface	14.15	10.49	7.73	6.13	4.635	3.645	2.768	2.371	1.818	1.547	1.245	1.077	.949	.848	.757	.63	.544	.478
	***18.632**	**12.986**	**9.07**	**7.046**	**5.10**	**4.016**	**3.003**	**2.556**	**1.975**	**1.649**	**1.328**	**1.137**	**1.**	**.893**	**.793**	**.664**	**.576**	**.50**
Weight per lin. ft., lbs	.241	.42	.559	.837	1.115	1.668	2.244	2.678	3.609	5.739	7.536	9.001	10.665	12.34	14.502	18.762	23.271	28.177
	* **.29**	**.54**	**.74**	**1.09**	**1.39**	**2.17**	**3.**	**3.63**	**5.02**	**7.67**	**10.25**	**12.47**	**14.97**	**18.22**	**20.54**	**28.58**	**37.67**	**43.0**
No. of threads per inch	27	18	18	14	14	$11\frac{1}{2}$	$11\frac{1}{2}$	$11\frac{1}{2}$	$11\frac{1}{2}$	8	8	8	8	8	8	8	8	8
Length thread to cut	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{7}{8}$	1	1	1	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$
Couplings external diameter	.5628	.7187	.8750	1.000	1.312	1.625	1.937	2.125	2.75	3.25	3.812	4.875	4.937	5.406	6.031	7.406	8.25	9.187
Casing, External diameter	**3**	**$3\frac{1}{4}$**	**$3\frac{1}{2}$**	**$3\frac{3}{4}$**	**4**	**$4\frac{1}{4}$**	**$4\frac{1}{2}$**	**$4\frac{3}{4}$**	**5**	**$5\frac{1}{4}$**	**$5\frac{1}{2}$**	**6**	**$6\frac{5}{8}$**	**7**	**8**	**$8\frac{5}{8}$**	**9**	**10**
Internal diameter	2.75	3.	3.25	3.5	3.75	4.	4.25	4.5	4.75	5.	5.187	5.625	6.25	6.625	7.625	8.25	8.625	9.625
Thickness	.109	.12	.12	.12	.134	.134	.134	.134	.148	.148	.148	.165	.18	.18	.18	.203	.203	.203
External circumference	9.424	10.210	10.995	11.781	12.566	13.351	14.137	14.922	15.708	16.493	17.278	18.849	20.813	22.991	25.132	27.096	28.274	31.415
Internal circumference	8.639	9.424	10.210	10.995	11.781	12.566	13.351	14.137	14.922	15.708	16.297	17.671	19.635	20.813	23.954	25.918	27.096	30.327
Area external diameter	7.068	8.295	9.621	11.045	12.566	14.186	15.904	17.721	19.635	21.648	23.758	28.274	34.472	38.485	50.265	58.426	63.617	78.540
Area internal diameter	5.939	7.068	8.295	9.621	11.045	12.566	14.186	15.904	17.721	19.635	21.135	24.850	30.680	34.472	45.664	53.456	58.426	72.760
Weight per ft. lbs	3.33	3.96	4.28	4.60	5.47	5.85	6.17	6.55	7.58	8.0	8.40	10.16	11.15	11.90	13.65	14.60	16.76	21.00
No. threads per inch	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	$11\frac{1}{2}$	$11\frac{1}{2}$	$11\frac{1}{2}$
Couplings external diameter	3.5	3.781	4.0	4.25	4.625	4.687	4.937	5.218	5.562	5.781	6.062	6.625	7.125	7.687	8.625	9.312	9.75	10.

*Heavy figures indicate wherein "STANDARD" and extra strong pipe differ

than the actual inside diameters) in common fractions; next, beneath, is the actual outside diameters in light face figures. There being but one line, and in light face figures indicates that Standard or Merchants pipe and "card weight" pipe (also referred to as "Extra strong") have the same outside diameters. This is imperative in order to have one set of standard pipe dies thread both weights of pipe. Double Extra Strong pipe also has the same outside diameter as standard pipe, and thus, one set of dies will thread all weights. In this way a multiplication of tools and a serious confusion of pipe fittings sizes are avoided, to say nothing of the difference i ncost of work. The heavier grades of pipe are regularly shipped from factory without threads. The third and fourth lines of the table give internal diameters, the light face figures standing for standard, and the black face for the heavier pipe. Below, likewise, is the thickness of walls, showing the difference in the walls of corresponding sizes. Thickness of wall determines the difference in internal diameters, internal circumferences, internal cross-sectional areas, lineal feet of pipe to equal one square foot of interior surface, weights per foot, etc., all of which are contrasted in the table. These differences are of importance in many ways. The number of threads per inch of screw are Western Standard and prevail with all American product. All pipe sizes larger than given have 8 threads to the inch. Threads taper about $\frac{1}{16}$-in. per inch of screw for the thickness of solid dies; when long screws are cut that portion which passes through the die has parallel sides; the tapered portion can be prolonged with adjustable dies, the starting thread being accordingly reduced in diameter (across the end of the pipe). The number (length) of threads to cut, for joining pipe and fittings may be varied to agree with circumstances,—some short radius fittings are too short in the parallel portions of wall to make-up on "Factory" threads without restricting the bore of pipe and fitting or butting out the back of the fitting. Some departures from standard lengths of threads are also necessary for short (thread sockets) bodied valves and cocks.

Except where capacities have been figured very close on the standard pipe basis, a change to heavier pipe would make no perceptible difference in results in any but the smaller sizes, for which one size larger should be used. When heavy pipe is predetermined on, deliveries and carriage should be figured on the reduced areas. While seldom considered, the difference between interior and exterior surface per unit length should be noticed where very exact results are sought, whether the case is one of loss of heat from, or absorption by, the contents of the pipe. Regardless of the weight of pipe,—interior surface is the real measure of heat transmission.

Below the pipe data are Well Casing sizes, contrasting their various dimensions, areas, weights, etc. In drilling and casing wells, several

casings are frequently used, one within the other, in order to "case off" various fresh and mineral waters and salt brine, especially if drilling for oil or gas instead of water,—smaller and smaller tools being operated through the successive stacks of casing.

Of the casing data given that which betrays next smaller size, coupled, that will lower, with reasonable margin, through a given size is oftenest called for, though there are many other instances of need for full information about casing. Light weight casing is sometimes used for exhaust steam heating,—its surface measures and areas shown by the table then come into play. There are some heavier weights made than shown in the table, and on which, in the larger sizes, a little coarser thread is cut. The threads given are standard. The difference between pipe and casing threads should be noted,—$\frac{1}{2}$-in. gas pipe has the same number of threads per inch of screw as is shown for 8-in. casing.

To illustrate the general application of the data given in Table XV and the importance of placing the various elements in intimate contrast, a few random instances of actual use are given in the following examples:

With a view to economy in providing well water and storage as early as he could afford it, a farmer during the previous season has had a 5-in. inside diameter well-casing hammered down by a portable drilling outfit that happened to pass his premises. The plumber is now to erect storage facilities and a gasoline-engine operated pump and desires to use the largest suction pipe that will go down. With a 50-ft. drop swinging, and tubular cylinder in the line, he knows from experience that there may be some *flat* or *dent* in the casing, or the suction may make-up slightly out of alignment. By inspecting the table, he finds the margin of play between 5-in. casing and the outside diameter of $3\frac{1}{2}$-in. pipe couplings is too little to trust, so he elects a 3-in. suction,—it will give ample room for any variation in size of couplings and alignment of pipe.

Somewhat similar conditions prevail in another case. The water shows a tendency to rust out casing rapidly. The plumber renews a line with 4-in. galvanized water pipe and swings his lift-pipe by a threaded flange run over a long screw and lock-nutted in place; $2\frac{1}{2}$-in. pipe is by the table seen to give a little over $\frac{3}{4}$-in. space to work on.

A $6\frac{1}{4}$-in. interior diameter casing is in place. The water is within easy suction limit; a power pump with storage is desired; the place is remote from mechanics; to trust to the power pump only is to court water famine sooner or later while repairs are being made; it is decided therefore to locate a good hand pump near the power pump in order to furnish fresh drinking water direct from the well and to serve in case of accident to the power operated pump or machinery. Inspection of the table shows that a $2\frac{1}{2}$-in. power suction will permit dropping in

along side of it a $1\frac{1}{2}$-in. hand pump suction, with $\frac{7}{8}$-in. play as couplings pass each other,—a 3-in. suction for the power pump would require perfect condition and alignment of all lines to avoid hanging when drawing or lowering one of the lines.

A flowing well results from sinking a $5\frac{5}{8}$-in. inside diameter casing. The community is short on $5\frac{5}{8}$ casing; the table is inspected as a means to discover a solution of the problem "how to pipe the flow some distance"; the outside diameter of a casing coupling or socket of that size is seen to agree with the exterior diameter of 6-in. water pipe of which there is an abundance at hand; therefore, a pipe thread is cut on one end of a casing coupling to receive one end of a 6-in. pipe coupling, and the problem is solved without delay,—the two couplings will form a transition piece from *casing* to *pipe*, with the end diameters *right* and number of threads to the inch at each end, *proper*.

A rather permanent stretch of "back-water" is found in a swag in the course of a 5-in. temporary gas line across country. Being inland and without a vestige of craft it promises to furnish an expensive aggravating piece of work to cross with the line, until floatation is thought of. An inspection of the table develops that a $4\frac{3}{4}$-in. inside diameter casing displaces 235 cu. in. per linear foot, equal to one gallon which weighs 8.3 lbs.; buoyancy is equal to the weight of water displaced and the table shows the casing to weigh but 7.58 lbs. per foot, leaving $\frac{3}{4}$-lb. per foot, margin for extra weight of couplings over pipe, and the possible 5 per cent. maximum variation in weight usually named in pipe makers' contracts. So, it is a rapid and easy job to plug the forward end, join length after length and shove $4\frac{3}{4}$-in. casing across, floating; join to the line and sink it by weighting, if sinking is necessary. The outside diameter of the pipe is the same size as the external diameter of the casing couplings and the transitions are made from *line* to *casing*, and from *casing* to *line* by cutting a pipe thread *on* one end of two casing couplings. Any light wood timber can be roped to the line of casing to tide across if the buoyancy of the pipe is depreciated from any cause. Should the job be projecting a pump suction out from shore line instead of *crossing* water, much the same sort of proceeding is an easy way to accomplish the work. Little flotation margin is needed if the nature of the work permits a brush cradle to hold the line off the bottom when sunk. If metal wheels or legs are to be used their weight must be taken into account and sufficient displacement over weight secured by selection of sizes, or, the equivalent of deficiency must in absence of favorable weight with size, be provided in the shape of detachable buoys of timber or casks.

Endless usages of the data in the table could be cited but the foregoing are enough to suggest the value and wide application of the figures given, though they are and cannot be other than approximations. Be-

sides the regular tubes mentioned, in black and galvanized, asphalted pipe, special "drive-well" pipe, boiler tubes, and others can be had in various weights in wrought iron and different kinds of steel, according to the service intended for.

CHAPTER XVII

Wrought-Pipe Supporting Columns with Square End Bearing

Pipe awning posts, pavilion posts, girder posts to carry upper floors of wide store rooms, and stanchions for various services are frequently called for by builders and supplied by the plumber. The purchaser and plumber are both often in doubt as to how great a load a column of a certain size and length will support. The accompanying formula with its interpretation and the tabular strengths per square inch of section will avoid any haphazard filling of such orders. When practicable the interior of the pipe should be swabbed with some protective coating and painted outside, because if iron or steel is left exposed to the atmosphere it unites with oxygen and water to form rust. The ends are to be fitted with good flanges well screwed on, and at least one end (the upper) closed. The formula is:

$$\left.\frac{40000}{1+\frac{(12\,l)^2}{4500\,\mathbf{d}^2}}\right\} = \left\{\begin{array}{c}\text{Ult.}\\ \text{Stgth.}\\ \text{of}\\ \text{1-Sqr.}\\ \text{In. of}\\ \text{section}\end{array}\right\} \times \left\{\begin{array}{c}\text{Sqr.}\\ \text{Ins.}\\ \text{in cross-}\\ \text{section}\\ \text{of}\\ \text{column}\end{array}\right\} \div 4 = \left\{\begin{array}{c}\text{Safe}\\ \text{load}\\ \text{for}\\ \text{column}\end{array}\right\},$$

In which **l** equals the length of the column in feet and **d** equals the nominal diameter or stock, size of the pipe, in inches, and 40000 equals the ultimate strength of wrought iron in pounds per square inch.

Example showing application of the formula: A pipe $\frac{5}{16}$-in. thick, 10 in. diameter and 10 ft. long will sustain what safe load, with the ultimate strength reduced by a factor of 4. Following the formula: 10-in. diameter$\times$10=100, the diameter squared; 100$\times$4500=450000. 12$\times$10 ft. length=120$\times$120=14400, the length by constant 12, squared. 14400 divided by 450000=0.032. 0.032+1=1.032, which divided into 40000=38760,—the failing point (ultimate strength) in pounds per square inch of the cross-sectional area of a pipe, of the assumed diameter and length, used as a *column*. The circumference of 10 is 31.42 in., which, multiplied by the assumed thickness, $\frac{5}{16}$-in.,=9.82 -in. 9.82$\times$38760=380623 lbs. total strength. This divided by 4, the usual factor for a safe stationary load for hollow wrought columns= 95155, the safe load in service that the column will stand. This corresponds to the first result given in the Table XVI, in which the top line of figures represents lengths of pipe columns in feet divided by diameter in inches.

The number set below the proportional number is in each case the

ultimate strength per square inch of section of column of length and diameter indicated by the proportional number above it. It is evident from this arrangement that columns 5 ft. long by 5 in. diameter; 6 ft. long by 6 in. diameter, 7 ft by 7 in., 8 ft. by 8 in., etc., will all bear the same load per square inch of metal section. Likewise, 8 ft. long by 4 in. diameter; 12 ft. by 6 in., and 16 ft. by 8 in. are of the same strength, and so on to the end, that by inspection, the strength per square inch of many sections may be read from the table without solving for the ultimate strength per square inch.

Table XVI. Ultimate Strength of Pipe Columns per Square Inch of Section

Length divided by diameter	**1.0**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**	**1.6**
Lbs. per sq. in.	38,760	38,510	38,240	37,960	37,640	37,310	36,980
Length divided by diameter	....	**1.7**	**1.8**	**1.9**	**2.0**	**2.1**	**2.2**
Lbs. per sq. in.	....	36,620	36,240	35,860	35,460	35,050	34,640
Length divided by diameter	....	**2.3**	**2.4**	**2.5**	**2.6**	**2.7**	**2.8**
Lbs. per sq. in.	....	34,210	33,770	33,330	32,890	32,430	31,980
Length divided by diameter	....	**2.9**	**3.0**	**3.1**	**3.2**	**3.3**	**3.4**
Lbs. per sq. in.	....	31,520	31,060	30,590	30,130	29,660	29,200

Wrought pipe columns when exposed to outside weather should always be kept thoroughly painted and should be so erected that the interior is practically air tight, because the interior cannot be reached when repainting, and if it is not protected, chance circulation of moist air will, in time, be most certain to expose the iron to corrosive influences and thus begin a never ending deterioration that would ultimately lead to serious results.

As an extra precaution against possible failure from interior decay the interior of such columns may be filled with a lean mixture of concrete or cement.

CHAPTER XVIII

Ratio of Pipe Capacities

Tables have been calculated to show the relative carrying capacity of various sizes of pipe to those of less diameter. When based on nominal sizes they are generally nearer correct for the ordinary sizes of extra strong pipe, as in these the actual internal diameters *approximate* nominal inside diameter. The number of one equal to the other, friction included or allowed for, is, however, much too high, when it comes to actively supplying at one and the same time the number of small pipes stated. These tables would answer better as a guide to determining the number of services a main will supply because service lines are not all in simultaneous use. For use with standard weight pipe (most frequently used) the ratios of most tables fall wide of the mark on smaller sizes when all the features of practice are considered

An example: The nominal diameter of $\frac{1}{2}$-in. pipe = .5,—nominal area = .1963; actual inside diameter = .623,—actual area = .3048; difference in areas = .1084,—about $\frac{1}{3}$. This excess of actual over nominal area in $\frac{1}{2}$-in. is equal to about $\frac{1}{9}$ of the actual area of 1-in., and the excess of four $\frac{1}{2}$-in. pipes equals nearly half of the actual area of 1-in. which is "twice the diameter" and generally referred to as four times the area of $\frac{1}{2}$-in. The nominal diameter of 1-in. = 1.0,—nominal area = .7854; actual inside diameter = 1.048; actual area = .88; difference in areas = .09+, about $\frac{1}{10}$. Actual against actual area, the aggregate of *three* $\frac{1}{2}$-in. pipes is *more* than one 1-in. Doubling the *diameter does* quadruple the area, but the statement is too often understood to mean that a commercial pipe of a given size will equal in area, four pipes of half the size, a proposition decidedly untrue in some instances.

It is easily seen that a table of this character should not only be made to take into account the excessive friction of the lesser sizes but should also be based on actual diameters with due allowance for the average burr resulting from cutting off, incrustation, etc. A feature of the Table XVII, taken from Professor R. C. Carpenter's work on heating and presented in full-face type, seems to come nearer than any other to answering this purpose, though he says no more than that it was especially calculated and that allowance for friction is made.

The service ratios of capacities have been determined by various formulae, the simplest, though perhaps not quite as accurate, being:

$$R \propto \sqrt[\frac{5}{2}]{\frac{D}{d}},$$

Table XVII. Ratio of Pipe Capacities

Combined Branch Mains Equivalents	Symbols		A	B	C	D	E	F	G	H	J	K	L	M	N	O
	Nominal Inside Diams.	½	¾	1	1¼	1½	2	2½	3	3½	4	4½	5	6	7	8
	½	**1.**	**2.**	**3.75**	**7.6**	**11.3**	**19.**	**37.**	**55.**	**80.**	**108.**	**146.**	**188.**	**290.**	**427.**	**595.**
		1.	2.25	4.	6.25	9.	16.	25.	36.	49.	64.	84.	100.	144.	196.	256.
	¾		**1.**	**1.8**	**3.7**	**5.4**	**9.**	**16.7**	**26.**	**39.**	**53.**	**70.**	**90.**	**143.**	**210.**	**295.**
			1.	1.75	2.75	4.	7.1	11.1	16.	21.75	28.1	36.	44.5	64.	87.1	113.75
	1			**1.**	**2.**	**3.**	**5.**	**9.**	**15.**	**27.**	**30.**	**39.**	**53.**	**80.**	**117.**	**165.**
2A				1.	1.6	2.25	4.	6.25	9.	12.25	16.	20.	25.	36.	49.	64.
	1¼				**1.**	**1.5**	**2.6**	**4.5**	**7.5**	**10.5**	**15.**	**19.5**	**25.**	**39.**	**57.**	**80.**
2B					1.	1.4	2.5+	4.	5.75	7.8	10.25	13.	16.	21.4	31.3	41.
	1½					**1.**	**1.8**	**3.1**	**4.7**	**7.**	**10.**	**13.5**	**17.**	**26.**	**38.**	**54.**
2C						1.	1.75	2.75	4.	5.4	7.1	9.	11.	16.	22.	28.
	2						**1.**	**1.83**	**2.9**	**4.**	**5.8**	**8.**	**10.**	**16.**	**23.**	**32.**
2D							1.	1.5	2.25	3.06	4.	5.	6.25	9.	12.25	16.
2D & 1C	2½							**1.**	**1.7**	**2.5**	**3.5**	**4.7**	**5.9**	**9.3**	**13.7**	**19.**
1E & 1D								1.	1.45	1.9	2.5	3.25	4.	5.75	7.8	10.25
1F & 1E	3								**1.**	**1.5**	**2.4**	**2.7**	**3.5**	**5.4**	**7.7**	**11.**
2E & 1B									1.	1.3	1.75	2.16	2.75	4.	5.4	7.
2F & 1D	3½									**1.**	**1.4**	**1.8**	**2.5**	**3.7**	**5.8**	**7.6**
1G, 1E & 1D										1.	1.3	1.6	2.05	2.9	4.	5.25
3E & 1D																
1H & 1F	4										**1.**	**1.3**	**1 7**	**2.7**	**4.1**	**5.25**
2G & 1E											1.	1.25	1.5	2.25	3.06	4.
1G, 1F & E																
1H & 1G	4½											**1.**	**1.4**	**2.**	**3.3**	**4.1**
1J & 1F												1.	1.25	1.8	2.4	3.1
2G & 1E																
1J & 1G	5												**1.**	**1.6**	**2.5**	**3.2**
1K & 1F													1.	1.4	2.0	2.5
1J, 2E & 1D																
2J & 1G	6													**1.**	**1.5**	**2.**
3G, 1F & 1E														1.	1.3	1.75
2F & 7E																
1M & 1J	7														**1.**	**1.4**
1L, 1J & 1G															1.	1.3
3J & 1E																
2M	8															**1.**
1M, 1L & 1J																1.
1L, 2J & 3G																
Lin. ft. pipe per sq. ft. of outside surface				2.9	2.3	2.0	1.6	1.3	1.1	.95	.84	.76	.68	.57	.5	.44
Sq. ft. surface per lin. foot of pipe				.34	.43	.49	.62	.75	.92	1.04	1.18	1.3	1.45	1.75	2.	2.25
Lin. ft. of pipe containing one U. S. gallon				22.	13.	9.5	5.75	.75	2.6	1.93	1.5	1.2	.96	.66	.5	2.84

R, standing for the number of little pipes the larger one will supply; **D** for the diameter of the big pipe, and **d** for the diameter of the little pipe, and meaning that the ratio varies as the square root of the fifth power of the quotient derived by dividing the diameter of the big pipe in inches by the diameter of the little pipe in inches.

Referring to Table XVII, the letters along the top are symbols for convenience in determining the number and sizes of branch mains their respective sizes will supply. The same symbols are given in the schedule of combinations of branch mains given in the left column opposite the same sizes as also bear them at the top of the table. For example: in the branch main equivalents at the left of 3-in. nominal diameter is found, one **"F"** and one **"E"**; two **"E"** and one **"B."** Finding the sizes under symbols along the top of table, this is interpreted to read: One 3-in. main will supply one $2\frac{1}{2}$-in. branch main and one 2-in. branch, or, if the branches in the job require other sizes, it will instead, supply two 2-in. mains and one 1-in. Three of the different combinations that a 4-in. main will supply are given. Interpreting the symbols at the left of 4-in. diameter it is found that a 4-in. main will supply:—one $3\frac{1}{2}$-in. main and one $2\frac{1}{2}$-in.; or, two 3-in. and one 2-in., or, one 3-in., one $2\frac{1}{2}$-in. and one 2-in. The combinations given for the other sizes are interpreted in the same way.

Throughout the body of the table, in full-face type are given the number of smaller pipes that one of another and larger size will supply. To use the table for this purpose: How many $1\frac{1}{4}$-in. pipes will one $3\frac{1}{2}$-in. pipe supply? Answer: Trace down the vertical column from $3\frac{1}{2}$-in. diameter, and to the right in the line of full-face figures leading from $1\frac{1}{4}$-in. diameter,—at the intersection will be found 10.5,—$10\frac{1}{2}$ $1\frac{1}{4}$-in. pipes equal one $3\frac{1}{2}$-in. in carrying capacity. Tracing from $2\frac{1}{2}$-in. to the right to under $3\frac{1}{2}$-in. finds 2.5, showing that a $3\frac{1}{2}$-in. pipe will supply two and one-half $2\frac{1}{2}$-in. pipes. The ratio of carrying capacity of the greater to the lesser of any other two sizes is found in the same way.

In light-face type in the lower lines of the complets are given, approximately the number of smaller circles of which the combined area equals that of a larger, found at the intersections as directed above. For example, under 4-in. diameter, in line with 2-in. diameter on the left is found 4, showing the aggregate of four 2-in. circles to equal that of one 4-in. The word circle is used to avoid confusion with inside *pipe diameters* which are greater than the nominal diameters given.

In the three lines along the bottom of the table under the respective sizes is given the linear feet of pipe required to equal one square foot of external surface; the square feet of surface, per linear foot of pipe, and the linear feet of pipe that will hold one U. S. gallon. This data is often very convenient.

CHAPTER XIX

The Flow of Water Through Pipes

The author has puzzled long over the problems of deliveries of water under various heads length and sizes, in the hope of being able to present to his fellow workmen some simple, easily applied formula that would cover the range of all ordinary practice without serious error, and now does not hesitate to say that it is all but a vain proposition to whoever undertakes it. The inherent complexity of the subject prohibits memory being the ready medium and the circumstances under which pipe fitters generally work not only makes intricate calculations extremely irksome but also discourages the frequency of resort to figure—necessary, to get quick trustworthy solutions, without which no real benefit is long to be derived.

The effort to find a simple procedure is not without reward, however. It is worth no little to a mechanic to know how to solve these problems in the simplest manner and what follows under the above head is worth the close attention of every practical mechanic in the country.

Whether one pursues the subject of Hydraulics beyond the point necessary for practical purposes, every one should be a little acquainted with the prime factors of the subject. The flow of water in pipes and channels and bodies falling freely are governed by the same laws, friction being the element that causes the marked difference in velocity for equal heights of fall. In one second a body falling in air, acquires a velocity of 32 feet and falls through the average of its acquired (accelerated) velocity,—16 feet. Acceleration is never increased beyond 32 ft. per second, acquired in the first second, and the distance fallen in feet is in proportion to the square of the time of falling, in seconds. Then:

With time of fall known: Multiply seconds falling by 32 to find acquired velocity; multiply square of the seconds falling by 16 to find the distance fallen.

With the distance fallen known: Divide the distance fallen by 16 and the square root of the quotient will be the time of falling in seconds; multiply the distance fallen by 64 and the square root of the product will be the velocity.

With the velocity known: Divide the velocity by 32 to find the time in seconds; divide the square of the velocity by 64 to find the distance in feet. More accurately stated a body falls 16 ft. and 1-in. in one second,—the fraction is ignored in all of the above. But for Friction, the flow of water in pipe and channels would be as simple as the above and actual instead of *theoretical* velocity would be represented by $\mathbf{V} = \sqrt{\mathbf{gh}}$; that is,

32 (32 equals gravity,—**g** in the formula) multiplied by the height, (called *head* in water problems and represented by **h** in the formula) and then the square root of the product extracted and read *velocity in feet per second.* If 50, as the height, be substituted for **h** in the formula the solution is $2 \times 32 = 64 \times 50 = 3200$. The square root of 3200 is 56.56 and equals the theoretical velocity in feet. In practice, a 50-ft. head or its equivalent, 21.65 lbs. pressure, gives a far lower velocity, being modified by character and extent of the surface the water travels over, changes of direction, shape of inlet hole where water is admitted to conduit, etc. All of these elements retard the flow of water. It is retarded velocity, of three kinds,—*uniform, accelerated* and *retarded*, that one has most to consider in water work. Accelerated by the head only the flow is retarded by every other feature. If a 4-in. stream is poured from a large pitcher at a high window, it may be less than one inch at the ground,—increase the height and the small stream will turn to individual drops, yet in each case the same amount of water is passing per interval of time, at all points of altitude in the stream,—*that*, is accelerated velocity, due to the action of gravity. An object projected upward is equally and uniformly retarded until the initial force imparted has been counteracted and velocity is zero,—*that* is retarded velocity,—acceleration is equal to retardation and in falling again the object would have the same velocity at equal heights as it had in rising, the air resistance to up or down motion being equal. Retardation of water flow in pipes is by no means so simple. The Torricellian formula given above shows a velocity of 56.56 ft. per second, friction not considered. Assume the delivery to be through 2-in. pipe: Then, $56.5 \times 12 = 678$ in. per second; 678×3.14, the square inches sectional area of a 2-in. pipe, equals 2129 cu. in. per second; $2129 \times 60 = 127740$ cu. in. per minute, divided by 231553 gals. theoretical delivery per minute through a 2-in. pipe with 50 ft. head. Compare this with the result of a formula designed to approximate the actual delivery, applicable where the head, or pounds pressure, diameter of pipe and length of pipe are known; written as a formula, thus:

$$\sqrt{\frac{D^5 \times H}{L}} \times 4.71 = \text{Cu. ft. of water delivered per minute,}$$

In which **D** equals diameter of pipe in inches raised to the fifth power, **H** the head of water in feet, and **L** the length of pipe in feet. Applied to a 2-in. pipe with 50-ft. head: $2 \times 2 = 4$; $4 \times 2 = 8$; $8 \times 2 = 16$; $16 \times 2 = 32$,—the fifth power of 2. The head $50 \times 32 = 1600$; 1600 divided by length, 50, equals 32. The square root of $32 = 5.65$; $5.65 \times 4.71 = 26.61$,—the cubic feet delivered per minute, which by $7.5 = 199.57$ gals. per minute delivered by a 2-in. pipe with 50-ft. head of water, through 50-ft. of pipe. This is about 36 per cent. of the theoretical delivery found by the Torri-

cellian formula above. Referring to Table XVIII giving deliveries per minute and friction loss in pounds for each 100 ft, by G. A. Ellis, C.E., 2-in. is shown to deliver 200 gals. per minute at a friction loss of pressure of 37.5 lbs. through 100 ft. The foregoing example being delivery through 50 ft. length, suppose half the friction loss in pounds as given in the table be taken and converted into feet of head,—something less than 44 ft. of head are derived, a discrepancy that would often be more than equalled in practice by variation in the condition of the pipe used.

If head, diameter and length were always known, it would be an easy matter to approximate the delivery as above, but they are frequently to be solved for, and in pursuing the subject in this way one finds it necessary to employ formulae for velocity, head, size, friction, quantity, etc., some of which require the substitution of one element from one table or another, according to the problem, of predetermined coefficients to suit conditions of the particular problem. Friction loss of head and velocity require the use of such tables with the proper formula.

The comparative area of any round pipe and another of twice its diameter is as 1 is to 4, and the aggregate circumference of 4 smaller to that of one larger equal to their combined area, is as *2 is to 1*. It is evident from these facts that some sliding scale allowance for friction is necessary,—hence the coefficients above referred to. As may be inferred from the foregoing, doubling the velocity of water in a pipe increases the friction four times, and reducing it to half the initial velocity decreases it to *one-fourth*,—another way of saying the same thing, and equal to saying that friction is proportional to the square of the velocity. If the velocity in one instance is *one* foot per second and in another, *two* feet per second: The square of one is *one* and the square of two is *four*; these squares are as 1 is to 4 and the resulting friction is likewise, not only in this but in *all* cases. If the friction is .24 lb. for *one* foot per second it will be .96 lb. for two feet per second; if it is 24 lbs. for a given size and delivery through 100 ft. of pipe at 8 ft. velocity per second, it will in the same, be 96 lbs. at 16 ft. velocity per second; so, also it will be 12 lbs. if through only half (50 ft.) the distance, at 8 ft. velocity per second, and only 48 lbs. at 16 ft. per second, through 50 ft.: Doubling the diameter for the same *delivery* reduces the friction to a thirtieth or less, while quadrupling the delivery through double the diameter gives about half the friction loss, at equal velocity in the two sizes. These statements are made clearer by citing a definite instance: Suppose a $\frac{1}{2}$-in. and a 1-in. pipe to each have a $\frac{1}{2}$-in. faucet attached at the end and both to be under the same pressure; if both are opened, the water flows only $\frac{1}{4}$ as fast through the 1-in. as it does through the $\frac{1}{2}$-in. This, on the score of velocity only, reduces the friction loss in the 1-in. to $\frac{1}{16}$ what it is in the $\frac{1}{2}$-in.; the same would be equally true if the velocity had merely been equally reduced in a pipe of the *same size*, but the size, too is dif-

Table XVIII. Head of Water in Feet Vertical Height Corresponding to Pressures in Pounds per Sq. Inch, 1-Lb. to 42.867 Lbs., and Pressures in Pounds per Sq. Inch for Heads, 2.3 Ft. to 228.64 Ft. Heads in Light Face Figures, Lbs. Pressure in Heavy

Feet of Head and lbs. per sq. in.		0	1	2	3	4	5	6	7	8	9
0–9	Ft.....	0	2.309	4.620	6.928	9.238	11.547	13.857	16.166	18.476	20.785
	Lbs....	**0**	**0.433**	**0.866**	**1.299**	**1.732**	**2.165**	**2.598**	**3.031**	**3.404**	**3.897**
10–19.......	Ft.....	23.095	25.404	27.714	30.023	32.333	34.642	36.952	39.261	41.570	43.880
	Lbs....	**4.330**	**4.763**	**5.196**	**5.629**	**6.062**	**6.495**	**6.928**	**7.361**	**7.794**	**8.227**
20–29.......	Ft.....	46.190	48.499	50.808	53.118	55.427	57.737	60.046	62.356	64.665	66.975
	Lbs....	**8.660**	**9.093**	**9.526**	**9.959**	**10.392**	**10.825**	**11.258**	**11.691**	**12.124**	**12.557**
30–39.......	Ft.....	69.284	71.594	73.903	76.213	78.522	80.831	83.141	85.450	87.760	90.069
	Lbs....	**12.990**	**13.423**	**13.856**	**14.289**	**14.722**	**15.155**	**15.588**	**16.021**	**16.454**	**16.887**
40–49.......	Ft.....	92.380	94.688	96.998	99.307	101.62	103.93	106.24	108.55	110.85	113.16
	Lbs....	**17.320**	**17.753**	**18.186**	**18.619**	**19.052**	**19.485**	**19.918**	**20.351**	**20.784**	**21.217**
50–59.......	Ft.....	115.473	117.78	120.09	122.40	124.71	126.02	129.33	131.64	133.95	136.26
	Lbs....	**21.650**	**22.083**	**22.516**	**22.949**	**24.382**	**23.815**	**24.248**	**24.681**	**25.114**	**25.547**
60–69.......	Ft.....	138.568	140.88	143.19	145.50	147.81	150.12	152.42	154.73	157.04	159.35
	Lbs....	**25.980**	**26.413**	**26.846**	**27.279**	**27.712**	**28.145**	**28.578**	**29.011**	**29.444**	**29.877**
70–79.......	Ft.....	161.662	163.97	166.18	168.59	170.90	173.21	175.52	177.83	180.14	182.45
	Lbs....	**30.310**	**30.743**	**31.176**	**31.609**	**32.042**	**32.475**	**32.908**	**33.34**	**33.774**	**34.207**
80–89.......	Ft.....	184.760	187.07	189.38	191.69	194.00	196.31	198.61	200.92	203.23	205.54
	Lbs....	**34.640**	**35.073**	**35.506**	**35.939**	**36.372**	**36.805**	**37.238**	**37.671**	**38.104**	**38.537**
90–99.......	Ft.....	207.852	210.16	212.47	214.78	217.09	219.40	221.71	224.02	226.33	228.64
	Lbs....	**38.970**	**39.403**	**39.836**	**40.269**	**40.762**	**41.135**	**41.568**	**42.001**	**42.436**	**42.867**

Friction-Loss in Pounds Pressure for each 100 Feet of Length, Discharge in Gallons of Water per Minute, and Velocity of Flow in Feet per second, in Clean Pipes of the Sizes in Left Column. Velocities in Light-Face Figures, Friction-Losses in Heavy

Gals. Disch'g per Minute		5	10	15	20	25	30	35	40	45	50	75	100	125	150	175	200
½-in..	Vel.	8.17	16.3	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Fr.	**24.6**	**96.0**	....	....	....	....	....	....	....	....	....	....	....	....	....	....
¾-in..	Vel.	3.63	7.25	10.9	14.5	18.1	....	....	....	....	....	....	....	....	....	....	....
	Fr.	**3.3**	**13.0**	**28.7**	**50.4**	**78.0**	....	....	....	....	....	....	....	....	....	....	....
1-in....	Vel.	2.04	4.08	6.13	8.17	10.2	12.3	14.3	16.3	....	....	....	....	....	....	....	....
	Fr.	**0.84**	**3.18**	**6.98**	**12.3**	**19.0**	**27.5**	**37.0**	**48.0**	....	....	....	....	....	....	....	....
1¼-in..	Vel.	1.31	2.61	3.92	5.22	6.53	7.84	9.14	10.4	11.7	13.1	19.6	....	....	....	....	....
	Fr.	**0.31**	**1.05**	**2.38**	**4.07**	**6.40**	**9.15**	**12.4**	**16.1**	**20.2**	**24.9**	**56.1**	....	....	....	....	....
1½-in..	Vel.	0.91	1.82	2.73	3.63	4.54	5.45	6.36	7.26	8.17	9.08	13.6	18.2	....	....	....	....
	Fr.	**0.12**	**0.47**	**0.97**	**1.66**	**2.62**	**3.75**	**5.05**	**6.52**	**8.15**	**10.0**	**22.4**	**39.0**	....	....	....	....
2-in...	Vel.	....	1.02	....	2.04	....	3.06	....	4.09	....	5.11	7.66	10.2	12.8	15.3	17.1	20.4
	Fr.	....	**0.12**	....	**0.42**	....	**0.91**	....	**1.60**	....	**2.44**	**5.32**	**9.46**	**14.9**	**21.2**	**28.1**	**37.5**

Gals. Disch'g per Minute		75	100	125	150	175	200	250	300	350	400	450	500	750	1000	1250	1500
2½-in..	Vel.	4.90	6.53	8.16	9.80	11.4	13.1	16.3	19.6	....	....	....	....	....	....	....	....
	Fr.	**1.80**	**3.20**	**4.89**	**7.00**	**9.46**	**12.47**	**19.66**	**28.06**	....	....	....	....	....	....	....	....
3-in....	Vel.	3.40	4.54	5.67	6.81	7.94	9.08	11.3	13.6	15.9	18.2	20.4	22.7	....	....	....	....
	Fr.	**0.74**	**1.31**	**1.99**	**2.85**	**3.85**	**5.02**	**7.76**	**11.2**	**15.2**	**19.5**	**25.0**	**30.8**	....	....	....	....
4-in....	Vel.	....	2.55	....	3.83	....	5.11	6.39	7.66	8.94	10.2	11.5	12.8	....	....	....	....
	Fr.	....	**0.33**	....	**0.69**	....	**1.22**	**1.89**	**2.66**	**3.65**	**4.73**	**6.01**	**7.43**	....	....	....	....
6-in....	Vel.	....	1.13	....	1.70	....	2.27	2.84	3.40	3.97	4.54	5.11	5.67	8.51	11.3	....	....
	Fr.	....	**0.05**	....	**0.10**	....	**0.17**	**0.26**	**0.37**	**0.50**	**0.65**	**0.81**	**0.98**	**2.21**	**3.88**	....	....
8-in....	Vel.	....	....	....	....	....	....	....	....	....	....	....	3.19	4.79	6.38	7.97	9.57
	Fr.	....	....	....	....	....	....	....	....	....	....	....	**0.25**	**0.53**	**0.94**	**1.46**	**2.09**
10-in...	Vel.	....	....	....	....	....	....	....	....	....	....	....	2.04	3.06	4.08	5.10	6.12
	Fr.	....	....	....	....	....	....	....	....	....	....	....	**0.09**	**0.18**	**0.32**	**0.49**	**0.70**

NOTE: With margin figures in upper table as "pounds," read "feet head" in light face, in body, of the table and with margin figures as "feet head," read "pounds" pressure in heavy face type.

ferent,—twice the size and four times the area. Therefore, while the water of 1 ft. velocity in the $\frac{1}{2}$-in. travels over 18.84 sq. in. of surface, an equal amount of delivery in the 1-in. would travel but $\frac{1}{4}$ of a linear foot and therefore come in contact with but 9.42 sq. in. of surface,—half the amount—and thus further reduce the friction, to half that indicated as the reduction due to velocity only, or $\frac{1}{32}$ as much in the 1-in. as in the $\frac{1}{2}$-in., under the conditions assumed. Practical results would vary some from the deliveries that may be inferred from this, on account of variation in the pipe and because friction does not retard the mass of a liquid uniformly throughout its section, as it does a solid. The interior of a column of water passing through a pipe moves the fastest,—the average speed of the whole contents is known as the "mean velocity."

It will be gleaned from what has been said that there is reason to believe that any one wishing to delve further into the problems of hydraulics than common practice demands would profit by studying a book devoted to that subject alone; while, if for satisfactory results with many problems for which formula can be given, a table of coefficients must also be used, a pipe fitter will but serve his own interest by using a table that will give the solution of a problem almost direct. To this end a combination of three tables, two of which are generally used together, is here introduced as Table XVIII. A tithe of the time that would be necessary to derive any benefit from several formulae not here considered will, if given to these tables generally be worth a hundred fold as much to the practical mechanic.

Being given together it is not necessary to turn from page to page to make common use of the tables. In the upper half of Table XVIII, vertical heights of a column of water from 2.309 ft. (the equivalent of one pound pressure per square inch) to 228.64 ft., advancing by the height necessary to equal a pound pressure are given in the upper lines of the couplets, in light-face figures. When converting pounds pressure into feet of head, the equivalent height of column (head) for the first 9 lbs. will be found in the upper light-face line under the respective numbers, heading the table and for this purpose assumed to be pounds. Heights for 10 to 99 lbs. will be found in light-face at the intersections leading from top and left column figures, which combined make up the number of pounds to be converted,—the left column carrying the even tens and the top line, the odd digits. Example: What head corresponds to 47 lbs. pressure? Answer: 108.55 ft., found at intersection of vertical column 7 and horizontal line leading from 40 in left margin. For 63 lbs., read 145.5 ft. at the intersection of 60 and 3, and so, forth.

In the *lower* lines of the couplets in the body of the upper half of the Table XVIII, in full face figures, are pounds pressure per square inch from .433 (the equivalent of one foot height of column) to 42.867 lbs., advancing by the fraction of a pound that equals one foot height of

column. When converting feet of head into pounds pressure, read the figures at the top of the vertical columns and in the side margin as "feet." The pounds are found in the body of the tables in *full-face* figures, in the same way as directed for the feet, above. Example: What pressure corresponds to 87 ft. of head? Answer: 80 is found in the side margin next to the bottom, and 7 at the top in its place in the line of digits, both being read for this purpose as "feet"; following down from 7, and horizontally to the right from 80, 37.67 lbs. are found in heavy figures at their intersection. For 31 ft., read 13.423 lbs. at the intersection of 30 and 1; for 20 ft., read 8.66 lbs. at the intersection of 20 and 0, and so, forth.

In the lower half of Table XVIII is the table by G. A. Ellis, C.E., already referred to, and with which the upper table is, for convenience, generally required. At the head of the table is given the discharge in gallons per minute, at different velocities for sizes of pipe ranging from ½-in. to 10-in. beginning with 5 gals. delivery per minute for ½-in. and ending with 1500 gals. per minute for 10-in. In the upper line of each couplet in the body of the table, in *light-face* type, will be found the velocities in feet per second corresponding to the gallons delivery per minute under which they stand, when the delivery is through 100 ft. of the size standing in the margin at the left. In the lower line of each couplet, in *full-face* type, will be found the friction loss in pounds for each 100 ft. of clean pipe of the size at the left through which the delivery passes, the friction losses being set under corresponding velocities and deliveries. Mr. Ellis's table serves in the solution of problems like the following:

A refinery at a high level requires 24,000 gals. of water per hr.; the pressure in the street main at that point is 40 lbs.; the refinery is 200 ft. from the main. What size service should be run into it? Answer: Table deliveries are in gallons per minute. So dividing 24000 by 60 equals 400 gals. per minute required. Tracing along the line of friction losses from 3-in. and down from 400, 19.5 lbs. friction loss per 100 ft. is found in full-face type at the intersection; $19.5 \times 2 = 39.$ lbs. for delivery through 200 ft. of 3-in. pipe. This is practically all of the available pressure. The future may demand a greater supply in the refinery, and other service further along on the main, will in time, as called for, probably need more water than would pass such a draft on the main unless it be a very large one. Therefore to avoid possible failure of an adequate supply both ways, 4-in. is determined on, which at 9.5 lbs. loss for 200 ft. will easily supply the amount, with 30 lbs. surplus to draw on.

The insurance companies demand that a country school, supplied from a tank 200 ft. distant, extend its 2-in. main service to the second floor 20 ft. above the grade, and maintain 15 lbs. pressure at fire hose

valves placed at that height as a means of fighting fire in its incipiency. The tank is too low to afford that pressure. How high will it have to be placed above the level of the second floor hose valves? It is unlikely that over 4 lines of hose would ever be in at once, or that one of them would use even 5 gals. per minute. It is best to live up to the spirit of the work, however, so take the friction loss for 30 gals. per minute, through 100 ft. of 2-in.,—.91 lbs. Then: the height from the hose valve to frost depth is 23 ft.; from building to tank structure, 200 ft.; up again to the level of hose valve, 23 ft., and, the head for 15 lbs. pressure at hose valve, according to the table, as found in light-face type at the intersection of 10 and 5, is 34.64, with a total of 280.64 ft. of pipe to deliver through, which by 0.91-lbs. friction loss per 100 ft., equal 2.55 lbs. total loss in the delivery. 2.55 lbs. for loss of pressure in the line, and 15 lbs. required at the hose valves, make a total of 17.55 lbs. The feet head for this pressure, taking even pounds, *18*, found at the intersection of 10 and 8, in light-face in the upper table, is 41.57 ft.,—the distance which the bottom of the storage tank should be placed above the level of the second floor hose valves. Adding 41.57 ft. to the distance of hose valves above the *grade line*, 20 ft., makes 61.57 ft.,—the distance bottom of storage tank should be placed above the grade line.

An elevated spring stream is $1\frac{1}{8}$-miles from a village; by measuring the section of flow over a weir it is estimated that it will easily fill a 6-in. pipe during the dry season; by leveling it is found to be 92 ft. above the plane of the village; how much water will it deliver to the village through a 6-in. pipe? Answer: one mile is 5280 ft.; $\frac{1}{8}$ mile is 660 ft.;—distance to village 5940 ft., say 60 times the length for which the friction loss equivalents are given in the lower table. In the upper table, at the intersection of 90 and 2, in heavy figures, 39.83 lbs. per square inch are found to correspond to a head of 92 ft. The friction loss in pounds for the distance will have to be within this limit. In the line of friction losses leading from 6-in., under 400 gals. per minute is found 0.65 lbs. loss for 100 ft. at 4.54 ft. velocity per second through 6-in. pipe. Multiplying this by 60 shows the total friction loss for the line to be 39 lbs. when delivering 400 gals. per minute. If 400 gals. were required per minute the spring would not be adequate, because the delivery should be accomplished with a margin of pressure of at least 10 lbs. per square inch in order to have the water rise to fixtures in the buildings. The height of the buildings to be supplied practically fixes the margin of pressure needed at the village end. If 350 gals. per minute are needed and the houses are one story, 0.5 lbs. loss per 100 ft. equals 30 lbs. and leaves 9.83 margin for service. If 300 gals. will be ample, 0.37 lbs. loss per 100 ft. equals 22.2 lbs. total loss and leaves 17.63 lbs. pressure for service,—equal to 40 ft. head, enough to reach the third floor or

ordinary buildings. If still less water, say 100 gals. per minute would answer, and the expense of a 6-in. line was an important question, look in the line of friction losses leading from 4-in., and under 100 gals. delivery per minute, is found 0.33 lbs. loss per 100 ft. $0.33 \times 60 = 19.80$ lbs., about half the available pressure, showing a delivery of 100 or more gallons per minute. 112 gals. are found by interpolating an arbitrary value for one not given in the table, in the form of the *mean* between the *mean* of the loss for 100 and for 150 gals., thus taken to equal 0.42 lbs. per hundred feet and leaving a margin of 14.63 lbs.,—sufficient to give very good service on the second floor.

Contemplating the installation of a motor, it is desired to know what velocity per second will result from 60 ft. head working through 300 ft. of 3-in. pipe. By the upper table, at the intersection of 60 and 0, it is seen that 25.98 lb. pressure correspond to 60 ft. head. In the lower table in the line of 3-in. friction losses per hundred feet, under 250 gal. is 7.76 lbs. friction loss for 100 ft., which by 3 gives 23.28 lbs. total loss, approximating the available pressure close enough. In the line of velocities, immediately over the friction loss at 250 gals. delivered through 100 ft. of 3-in., is the corresponding velocity, 11.3 ft. per second.

A 1-in. pipe barely supplies a battery of steam boilers, from a main carrying 12 lbs. pressure; how high would a tank have to be placed to supply an equivalent battery at another point, through 1200 ft. of $1\frac{1}{2}$-in. pipe? A stationary engineer would know the gallons delivery by the amount of steam used, but a plumber would find the water required by following the line of friction losses from 1-in. until the loss nearest the pressure named is found, 12.3 lbs. under 20 gals. per minute. At 20 gals. per minute through 100 ft. of $1\frac{1}{2}$-in. the friction loss is seen to be 1.66 lbs. $1.66 \times 12 = 19.92$, say 20 lbs. loss for delivery through 1200 ft. Therefore, the head in feet corresponding to 20 lbs. pressure will be the height at which the tank would have to be placed. In the upper table, at the intersection of 20 and 0, 46.19 ft. elevation is found to equal 20 lbs. pressure.

A hydraulic machine is taking water through a 1-in. pipe at 16 ft. velocity per second from a main service at the machine. It is desired to know what the drop in pressure will be at a new machine placed in a room 50 ft. distant and the water conveyed to it through 1-in. pipe. Following along the line of velocities, from 1-in. in the lower table, 16.3 velocity per second is found under 40. Immediately under the velocity is the corresponding friction loss in pounds, 48 lbs. for *100 ft.* The friction loss through 50 ft. only is sought however, and as previously indicated the resistance to constant flow is proportional to the length of delivery; accordingly, 48 lbs., the loss for *100* ft., is divided by 2 and 24 lbs. proves to be the drop in pressure for 50 ft. By inspecting the losses for other velocities it is found that by filling the press

cylinder only as fast, the drop in pressure would be but 6 lbs. plus. Either a low initial pressure or the cost of *time* in filling the press cylinder, might demand a pipe larger than 1-in.

The examples of use given are such as will occur in practice. The results are good approximates. If figures by the formulae for such, the results would still be approximates, and the time required for solution of problems would be greatly increased. Sufficient has been said to indicate the extended service which the tables of plate XVIII may be made to render.

PART II

CHAPTER XX

Lead Data

Lead is one of the most important of the base metals. It is a malleable, ductile, very inelastic, bluish colored heavy metal (atomic weight 206.4), obtained principally from Galena ore (sulphide) occurring in many countries, with the United States a leading producer. Lead is an ingredient of many alloys; it is the basis, by acid corrosion, for white lead which may be reduced to the metal base with a blow-pipe; it is the base, by heat, for the yellow-red lead monoxide called litharge, from which in turn red lead is produced. Lead is of low tenacity, 2000 lbs. average per square inch; specific gravity, 11.35; specific heat, .0314 at 98 deg. F.; weight, $6\frac{7}{12}$ ozs., or .41 lbs. per cubic inch; fusing point, 608 deg. F.; thermal conductivity, about $\frac{1}{2}$ that of iron, $\frac{1}{3}$ that of brass, $\frac{1}{10}$ that of copper, and $\frac{1}{14}$ that of silver; its expansion and contraction is excessive,—slightly more than for zinc, $\frac{1}{4}$ more than for silver, $1\frac{3}{4}$ times that of copper, $2\frac{1}{2}$ times that of cast iron and nearly 4 times as much as glass. These properties give it many distinct traits. Its resistance to acids fits it for use in chemical works tanks, when seamless or with seams joined by fusing the lead; its pliableness makes it easy to model by hand or machinery into pipes, traps and other forms required by the plumbing trade; its flexibleness in pipe form makes it easy to lay in obstructed trenches and in difficult courses in buildings; its low fusing point makes it easy to melt and the low latent heat of fusion causes a mass to melt quickly in the pot when fusion once begins,—its corresponding quick loss of fluidity facilitates speed in running joints, etc.; its low conductivity is an advantage in getting up a heat to wipe a joint, in soldering with the copper, in avoiding steam when dampness in the pipe is near and in keeping heat at the lead end when other metals are wiped to it. Its low tenacity is against it in that the thickness of wall required for heavy pressures advances the cost of lead pipe to a degree that makes it compete with the other materials on service merit alone. Great weight, small strength, inelasticness and the high coefficient of expansion are all elements of disadvantage under one condition or another, except the thickness and low tenacity permit frequent freezing without rupture from diametrical expansion at the point frozen, and when bursted from frost beyond the frozen point through the contents being crowded by extension of the ice core, the break is small and the original pipe is easily, quickly, and cheaply repaired.

Lead is not self-supporting in any form or position for more than a very short length; under tensile or torsional strain or pressure of contents it will not retain anything like original dimensions above ordinary atmospheric temperatures; it creeps into permanent wrinkles on roofs and in sinks and tanks where hot water is drawn, thus preventing drainage and weakening metal adjacent, to the point of crystalization or rupture,—these reasons make it unfit for hot service lines and stove connections. Abnormal shrinkage and softness limit its use as an element in the arts where casting, resilience, rigidity or surface resistance are indispensable.

Lead has been supposed to be severe on the health of plumbers, but even in the days of practically "all lead plumbing" there was nothing to fear as to health where the workman's personal habits of cleanliness were uniformly observed to a reasonable degree. Cleaning the hands thoroughly before eating is one essential often omitted in an effort to lengthen the short luncheon-time of fall and winter months.

Lead has in all but a few cases borne an unmerited reputation in the way of being supposed to frequently affect health through the poisoning of water supplies. Half a century of constant service on river water, (ordinarily next to rain water in solvent power) had failed through both wear and solvent action to enlarge the caliber of a pipe to a measurable extent. It is only in house pipes where the contents are comparatively still from 6 to 9 hours at night, as a rule, that pollution from lead may be admitted probable in the first drawing at morning. Even this limited possible source of danger (aside from pure rain water) is confined to rare instances. Many waters charged with material that are often supposed to favor continuous contamination, soon form insoluble protective compounds in the pipe,—sulphate, phosphate and carbonate of lead are examples. The lead of the pipe furnishes a new and more attractive base for the acid of the lime or some other material carried by the water to form these protective coatings.

If forewarned, and one need not be, of the deleterious character of a supply, the corrosive action may be prevented by coating the interior of the pipes with sulphide or chromate of lead through letting stand in them over night a saturated solution of:—for the sulphide,—sulphide of potassium; for the chromate,—chromate of potassa. If no desirable counteractive can be found, pipes of some other metal, galvanized iron or steel or brass pipe, or tin-lined lead pipe can be substituted for lead. Other metals are not all immune to the action of water. Their use at random on dangerous supplies may mean no more than contending with salts of zinc, iron, etc., in place of those of lead and it is probably safer when practicable, to discard a refractory supply than cater to its defects in the material or treatment of the conduit.

Rain water properly stored is comparatively pure and soft and thus

admirably suited to domestic and laundry purposes, and though the purer the water the quicker it attacks lead, (not considering water charged with corrosive salts) no attention is usually paid to or considered necessary as to the effects of lead upon it. Being largely the supply outside the limits of city systems, its storage for pressure is necessary and the lead-lined attic house tank, quite usual, is a superior feature for the purpose. If any precautions are taken, the tank lining, in contact with which the water remains longest, should first receive treatment. A thick coat of Trinidad asphalt applied hot with a stiff brush is doubtless the best protection for the tank and it is easily provided. For the pipe system the protective coatings above referred to and others not mentioned are applicable.

Lead is a cumulative poison making it difficult to assign the course, and of the few cases attributed to water affected by lead pipe, some were more than likely due to one of the many causes known to be far more prolific of lead poisoning than affected water has ever been shown to be.

It is by no means intended to here embody a treatise on the analysis of water and the chemistry of compounds carried by it and resulting in the affection of lead and itself to the detriment of the user. Such literature is profuse. Facts do not justify ill-advised discrimination against lead on that score. A few words further, bearing on the detection of impurities may, however, serve the reader in ordinary cases in lieu of a more expensive test, or at least indicate the importance of a thorough investigation: Turbidness is generally caused by soluble organic or solid matter in suspension which should be filtered out; disagreeable odor from water in a clean partly filled bottle that has been corked a few hours, or repulsive taste after heating indicates unfitness for domestic use; impure water becomes milky in a day or so when cleanly corked and exposed to light in temperate air, provided a little granulated sugar has been added. When testing for lead the percentage is usually so small that great reduction by boiling is necessary to increase the lead per volume to a degree more easily detected and care must be taken in the treatment to prevent concealing the lead in the shape of insoluble compounds. A saturated solution of bi-chromate of potassa is red; when added to lead affected water that has been sufficiently concentrated, a chrome yellow precipitate is formed, which, treated with nitric acid turns to a chrome red. A small fraction of a grain of lead to the gallon can be detected through a change in color by merely adding the bi-chromate solution. The smaller the amount of lead, the fainter the color. But very little of the bi-chromate should be added at a time, being sure by comparison (observing in contrast with pure water to which the solution should also be added similarly) that no change has occurred before adding more. This test is perhaps

not so delicate as the sulphuretted hydrogen test but is less complicated and more likely to give good results in the hands of an amateur. In boiling down the water some oxycarbonate and sulphate of lead may be formed; a little of a solution of citrate of ammonia will dissolve the latter and acetic acid the former. Turbidness may necessitate filtering the concentrated water.

Climate and cost, or both in cases, are largely prohibitive in this country to many uses which lead had been and is put to. Its structural service outside of plumbing is here practically confined to paint pigments, roof flashings, art window leading, damp-proofing courses in walls, leader expansion connections and sash weights. For joining cast water and low-pressure gas mains its use was universal and is still general. As a cold water conduit there are examples still in perfect condition, antedating the Christian Era. Modern street service lines of ordinary weight afford numberless instances of 60 years and more of continuous service under pressure without perceptible depreciation, even though the water carried often contained much sharp river sand or was sometimes loaded with minerals of a character supposed to "eat" lead very rapidly. In fact there are so many features of merit to recommend lead and so few objections based on reasonable tenable ground, that outside the ranks of the trade it has been almost wholly the short-sighted property owner who fathered abandoning lead without adequate cause. It will regain the lost ground wherever it has been put out of commission by lack of just appreciation of its fitness or failure to recognize its use as being to the true interest of the owner, which indirectly is, of course, in the best interests of the plumber.

The Table XIX sets forth much that is of interest to the plumber. While not conforming in detail to that of any manufacturer's list, all the sizes and weights of pipe mentioned are regular market product. Their presentation is not alone for the reader's benefit for reference,—they are also valuable aid in interpreting descriptive matter following the table and relating to pipe work.

For planning or estimating lead work the thickness of pipe required and the weight per linear foot are leading questions. Any information aiding in quickly and definitely settling these points is warmly welcomed by the trade. As with iron pipe the interior diameters govern in trade practice. These are given in decimal fractions in the table. The thickness of a size may be noted by subtracting the outer diameter from the inner and taking half the difference for the thickness. The figures to the right of the decimals are 10ths, 100ths, etc.; to the left, inches. The weights given in ounces may be changed into pounds and ounces mentally dividing by 16,—lead being reckoned by avoirdupois weight.

The symbols were originally intended to mark on each size, a uniformly graduated increase of strength,—say 15 per cent. Their application, by independent makers, to lists of sizes and weights that did not agree has somewhat confounded their significance to the trade. It is however much easier to associate with a symbol, a certain thickness of wall, the purpose used for, and the jobs and conditions under which it gives unquestioned service than to mentally keep track of the same data against a size given in fractions or decimals. The symbols are equally valuable to master and journeyman in this sense and are ready vehicles of thought easily grasped and retained. In applying them to the sizes given, it was necessary to have some regard to the limitations of commercial sizes; to keep in mind their original intent; to remember that plumbers in all parts of the country may bear them in mind and fix in memory factors of weight, strength, thickness, etc., regardless of what or whose product the local market affords. As the general tendency is to use pipe of too light weight, a point in favor of stronger pipe was made by taking advantage of the symbol of habit already fixed by custom to some extent, by erring on the "heavy side" in sizes used for pressure. Aside from these points, though it was not possible, the tendency was to have the same symbol appear on inside diameters of a "size" or "weight" of as near the same thickness of wall as practicable, thus signaling approximately equal thicknesses as quite as good if not a better basis, all things considered, than to endeavor to have the chain of symbols point out "weights" capable of withstanding equal pressures with the same

Table XIX. Lead Pipe—Approximates Dimensions, Weights, etc.

Sizes of $\frac{1}{8}$-in. Inside Diameter

Outer diameter in decimal	0.25
Weight per linear ft., ozs	$2\frac{1}{2}$

Sizes of $\frac{1}{4}$-in. Inside Diameter

Outer diameter in decimal	0.375	0.437	0.483
Weight per ft., ozs	5	8	11

Sizes of $\frac{3}{8}$-in. Inside Diameter

Outer diameter in decimal	0.483	.53	.562	.583	.61	.64	.70	.75	.78	.85
Symbols	—	AQ	XL	L	—	M	—	S	—	XS
Weight per linear ft., ozs	6	8	10	12	14	16	20	24	28	32

Sizes of $\frac{1}{2}$-in. Inside Diameter

Outer diameter in decimal	0.61	.624	.67	.70	.72	.764	.812	.85	.875	.96	1.0208	1.125
Symbols	—	AQ	XL	—	L	M	—	S	—	XS	XXS	—
Weight per ft., ozs	8	10	12	14	16	20	24	28	32	40	48	64

Sizes of $\frac{5}{8}$-in. Inside Diameter

Outer diameter, decimal	0.75	.78	.812	.84	.89	.92	.96	1.0	1.04	1.05	1.078	1.125	1.15	1.2	1.26
Symbols	AQ	—	XL	—	L	—	M	—	S	—	XS	—	XXS	—	—
Weight per ft., ozs	13	14	16	20	24	28	32	36	40	44	48	52	56	64	72

Sizes of $\frac{3}{4}$-in. Inside Diameter

Outer diameter, decimal	0.875	.89	.904	.92	.96	.98	1.015	1.062	1.078	1.125	1.15	1.166	1.22	1.26	1.31	1.35
Symbols	—	AQ	—	—	—	*XL	—	L	M	—	—	S	XS	XXS	—	—
Weight per ft. ozs	12	14	16	18	20	24	28	32	36	40	44	48	56	64	72	80

Table XIX—Cont'd

Sizes of 1-in. Inside Diameter

Outer diameter, decimal	1.18	1.187	1.22	1.25	1.265	1.29	1.34	1.37	1.41	1.53	1.60	1.65	1.75
Symbols	AQ	—	—	*XL	—	L	—	M	S	XS	XXS	—	—
Weight per ft., ozs	20	24	28	32	36	40	48	56	64	80	96	112	128

Sizes of $1\frac{1}{4}$-in. Inside Diameter

Outer diameter, decimal	1.41	1.45	1.47	1.483	1.53	1.58	1.625	1.65	1.70	1.75	1.81	1.89	1.97
Symbols	—	AQ	—	*XL	L	—	M	—	S	XS	—	XXS	—
Weight per ft., ozs	28	32	36	40	48	56	64	72	80	96	112	128	144

Sizes of $1\frac{1}{2}$-in. Inside Diameter

Outer diameter, decimal	1.66	1.70	1.75	1.78	1.81	1.84	1.89	1.95	2.035	2.093	2.187	2.31
Symbols	—	—	AQ	*XL	L	—	M	S	XS	—	XXS	—
Weight per ft., ozs	32	40	48	56	64	72	80	96	112	128	160	192

* Lightest weight of the size likely to give good service as a pump suction.

Sizes of $1\frac{3}{4}$-in. Inside Diameter

Outer diameter, decimals	1.97	2.03	2.09	2.156	2.265	2.416	2.5
Symbols	—	*XL	L	M	S	—	—
Weight per ft., ozs	48	64	80	96	128	160	192

Sizes of 2-in. Inside Diameter

Outer diameter, decimals	2.18	2.25	2.31	2.37	2.41	2.47	2.53	2.58	2.68	2.76
Symbols	AQ	XL	*L	—	M	—	S	XS	XXS	—
Weight per ft., ozs	48	64	80	96	112	128	144	160	192	240

Sizes of $2\frac{1}{2}$-in. Inside Diameter

Outer diameter, decimals	2.68	2.78	2.87	2.916	3.0	3.166	3.33
Symbols	AQ	*XL	—	L	M	S	XS
Weight per ft., ozs	56	80	112	128	176	224	288

Sizes of 3-in. Inside Diameter

Outer diameter, decimals	3.16	3.22	3.27	3.33	3.40	3.5	3.64	3.68	3.75
Symbols	—	AQ	XL	L	M	S	XS	—	XXS
Weight per ft., ozs	64	80	96	128	160	208	256	272	304

Sizes of 4-in. Inside Diameter

Outer diameter, decimals	4.15	4.20	4.25	4.30	4.375	4.5	4.625
Symbols	—	AQ	XL	L	M	S	XS
Weight per ft., ozs	80	96	128	160	192	256	336

Sizes of $3\frac{1}{2}$-in. Inside Diameter

Outer diam., dec.	3.687	3.72	3.875	4.0	4.08
Symbols	AQ	XL	L	S	XS
Weight per ft., ozs.	72	96	160	240	304

Sizes of $4\frac{1}{2}$-in. Inside Diameter

Outer diam., dec.	4.68	4.72	4.89	5.0
Symbols	AQ	XL	M	S
Weight per ft., ozs.	112	128	224	320

Sizes of 5-in. Inside Diameter

Outer diam., dec.	5.20	5.24	5.375	5.5
Symbols	AQ	XL	M	S
Weight per ft., ozs.	128	144	240	352

Sizes of 6-in. Inside Diameter

Outer diam., dec.	6.12	6.187	6.50	6.75
Symbols	—	AQ	XL	M
Weight per ft., ozs.	160	192	416	528

* Lightest weight of the size likely to give good service as a pump suction.

Weight per sq. ft. of Sheet Lead and Tin

Thickness, inches	$\frac{1}{64}$	$\frac{1}{43}$	$\frac{1}{40}$	$\frac{1}{32}$	$\frac{1}{27}$	$\frac{1}{24}$	$\frac{1}{20}$	$\frac{1}{16}$	$\frac{3}{64}$	$\frac{1}{16}$	$\frac{1}{13}$	$\frac{5}{64}$	$\frac{1}{11}$	$\frac{3}{32}$	$\frac{1}{10}$	$\frac{1}{9}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{2}$
Sheet tin, per sq. ft., lbs.	—	—	1.0	—	1.5	—	2.0	2.5	—	—	3.0	—	3.5	—	4.0	4.5	5.0	10.	20.0
Sheet lead, per sq. ft., lbs.	1.0	1.5	—	2.0	—	$2\frac{1}{2}$	—	—	3.0	4.0	—	5.0	—	6.0	—	—	8.0	16.	32.0

factor of safety. It is a fact however that sizes ranging from $\frac{1}{2}$-in. to 3 in. inside diameter and of the same commercial thickness, vary greatly in ultimate resistance.

It is difficult to offer a simple formula to determine "pressure adapted to" for the range of sizes. Authorities differ widely as to the tenacity of lead and different experimenters give various bursting pressures for the same size and weight of pipe. For water pressure and general strain combined, 5 lbs. per hundredth of an inch thickness of wall is a very good rule of thumb,—too low for the small sizes and too high for general service, on the very large sizes, but safe on the intermediate calibers most used. The tenacity of lead may be taken to be 2000 lb. per square inch.

To compute safe working pressures for lead pipe with a factor of safety of 5:

A—Multiply 2000 by twice the thickness of wall and divide the product by 5 times the internal diameter, both in decimal inches,—the quotient will be the working pressure. On approximately $\frac{20}{100}$ thick for all sizes, this gives a range of working pressures on 0.5 to 3.0-in. of from 320 lbs. on .5 in. to 53-lbs. on 3.0 in.

B—Solve just as above except substitute the outside diameter of the pipe when making a divisor. On the same sizes and thickness used with "A," this gives a range of working pressures beginning with 177 lbs. for the $\frac{1}{2}$-in. and ending with 47 lbs. for the 3-in.

C—Solve as above, using "A" divisors on all sizes over 1-in. diameter, and "B" divisors on all sizes 1-in. diameter and less. This gives a range of pressures from 177 to 53 lbs.

Internal pressure is seldom the only point to be considered and while the whole range of "A" and "B" pressures are within the factor of 5 limits, it is evident that the pressures given by "A" for small pipes is excessive, and by "B" rather low for the large sizes. "C" gives the higher pressures of "A" on the large, and the lower pressures of "B" on the small pipes,—a combination use of "A" and "B" far better for the whole range of sizes, all things considered, than either "A" or "B" alone gives.

It is the pipes of small caliber that constitute the terminals of pipe systems; that do service at drawing points, and that make up general house lines. They are often indifferently supported; partially suspended; subject to various strains, and suffering a variety of other deteriorating influences which the larger sizes are less frequently subjected to. The small sizes stand the principal shocks of reaction, strain of sag, torsion, suspension and possible corrosion. They are subject to the weakening effect of heat in hot service lines and to dilation from

freezing in exposed places. All of these features require a margin of strength, aside from that needed for mere static pressure, to insure enduring the certainties and incidents of long service, many of which cannot be justly assumed to require an allotment of metal when proportioning the larger sizes for service. Large sizes are, if used for pressure, generally in the ground, well supported, immune from frost, at an equal and moderate temperature, more remote from reaction, far removed from a host of depreciating features of building service and not, as used, as is often the case with other materials, likely to fall a prey to one of the many external corroding agents. It is seen from all this, to be best to combine the use of formulae **"A"** and **"B"** as directed in **"C,"** for general house lines, hot service, self-closing hydrants, ram deliveries, and ram drives up to 1-in. diameter. For ram drives over 1-in. diameter, use **"B"** divisors. Where economy is the prime factor, service lines, main runs in ground and cold house lines well protected from frost, strain and reaction, **"A"** divisors may be used.

It is evident that the rule for finding working pressure is reversable to determine the thickness when the working pressure and pipe diameter are known, thus:

D—Multiply the working pressure by five times the inside caliber and divide the product by 2000, and then by 2. The quotient will be the thickness of wall.

There are several ways to find the weight of a given pipe. Which is the best depends upon circumstances of the moment. There appears to be some difference in the density of lead due to milling or forcing through the press. Specific gravities of different kinds—lead in different stages of refinement—do not agree; maker's catalogued weights do not agree, due partly perhaps to the condition of the dies. So, for figuring on work, one should be familiar with how the actual weights compare with the catalogued weights of the pipe to be used. The weights given in Table XIX are those usually assigned, but they are merely approximations, varying considerably in some sizes. Inside diameter squared, multiplied by .7854 and subtracted from the outside diameter squared and multiplied by .7854 gives the true sectional area of a pipe wall, which multiplied by 12 obtains the cubic inches of lead in one linear foot of pipe; this multiplied by .41 reduces the cubic inches per foot to pounds per foot. Also, instead of multiplying by 12, and then by .41 to get the pounds per linear foot, that weight may be obtained by multiplying the cross-sectional area by 4.92, thus reducing the true area to pounds per foot directly. A still quicker and equally accurate method, is to merely subtract the square of the minor diameter from the square of the major and multiply the difference by 3.86. This produces pounds per lineal foot without entailing the work of multiplying twice by a decimal of four figures. The area of a circle is .2146 less

than its circumscribing square. 12 cylindrical or 9.42 cu. in. of lead weigh 3.8622 lbs. Hence the multipliers, 3.86 and 4.9 for linear feet of pipe in pounds, and .41 per cubic inch of lead, in pounds.

In Table XIX one weight of each of the several calibers most often used for ordinary pump suctions is marked with an asterisk. The object of the marking is to indicate the lightest weight per foot likely to give trustworthy service. The thickness marked will stand internal pressure to ten times that of the atmosphere, but for suction use the strain is from the outside and the requisite strength is never a factor of ultimate rupture. Collapse, from the lack of perfect circularity, tensile strain from suspension in cisterns, sag (stricture of caliber) from inherent weight where passing through walls, etc., are the elements of failure to be guarded against in selecting a lead suction pipe,—their singular and possible combined effect always demand a high factor of safety.

CHAPTER XXI

Safe Pan and Supply Safe Pipes

Lead-lined tanks never need a safe pan to take care of atmospheric condensation, if properly built, because the metal lining is encased within the wood which is a poor heat conductor, in such a manner that air cannot circulate in contact with the lead and no moisture can be deposited unless carried by the air to the cold surface and there chilled to below dew-point. Safes are sometimes placed under lead-lined wood-case tanks as an extra precaution to intercept possible leakage, but such are rarely seen.

Metal tanks of every form stable enough to stand alone uncased are provided with a safe pan because the atmosphere is in contact with the cold water-walls and there being nothing to restrict its circulation sufficient moisture is condensed to cause profuse "sweating" at times. Enough water thus drips from the exterior surface of the tank to alone demand the installation of a safe and means to keep it empty, and there is further reason for the safe as an exposed wall tank and connections are much more likely to freeze, if freezing is possible at all, than is a wood-case tank. A safe pan is therefore a feature of every inside tank job unless the tank is lead-lined, for though a metal tank can be covered to prevent sweating, as a steam drum is to retain heat, such covering is not a protection against leakage and its cost would frequently be no less, while a wood *stave* tank must have a safe on account of stave leakage.

In Fig. 50 are illustrated several methods of attaching iron safe pipes to iron pans. In case the metal is thick enough to tap and the tank is of a size to require but 2-in. pipe or less for overflow and leakage the safe pipe can be screwed into the safe pan metal as shown in sketch **W**, in which **S** is the safe pan; **P**, the pipe; **G**, a gasket; **L**, a lock-nut and **C**, a bee-hive strainer to be screwed into the thread tapped in the end of the safe pipe. The strainer is designed to keep obstructing matter out of the pipe. Some sizes of pipe and strainers with iron pipe thread which can be worked together in the way shown are: $1\frac{1}{4}$-in. safe pipe will tap on the interior for a 1-in. strainer; $1\frac{1}{2}$-in. will tap for $1\frac{1}{4}$-in., and $2\frac{1}{2}$-in. will tap for a 2-in. strainer. Unless a locknut is used the pipe thread should be cut short for the hole,—a full or factory thread screws through too far. It is better to use a full length thread cut "full" to suit so it will get tight by the time it screws through the plate, and then back a lock-nut up to the bottom moderately tight with a hard gasket between, as shown. This alters the leverage

power of pipe deflection strains to accord with the change of fulcrum and makes the pipe much less likely to be broken out of the hole.

If a large pipe is required it is best to have a pipe-flange riveted on to the bottom of the safe and the safe metal calked to it inside. A pipe flange with gasket may be bolted to the safe, the gasket and the metal surfaces being covered with a thick paint of red lead or litharge mixed with shellac varnish. The mixture should be made after everything else is ready, applied quickly and bolted up tight as fast as possible, because it sets in a few minutes. The number and size of bolts used should be the same as for standard flanged steam pipe fittings of the same pipe size as the flange.

Sketch X, Fig. 50, shows the safe pipe attached by means of two lock-nuts and gaskets. **S**, is the safe; **L**^{1}, a lock-nut; **E**, a sheet

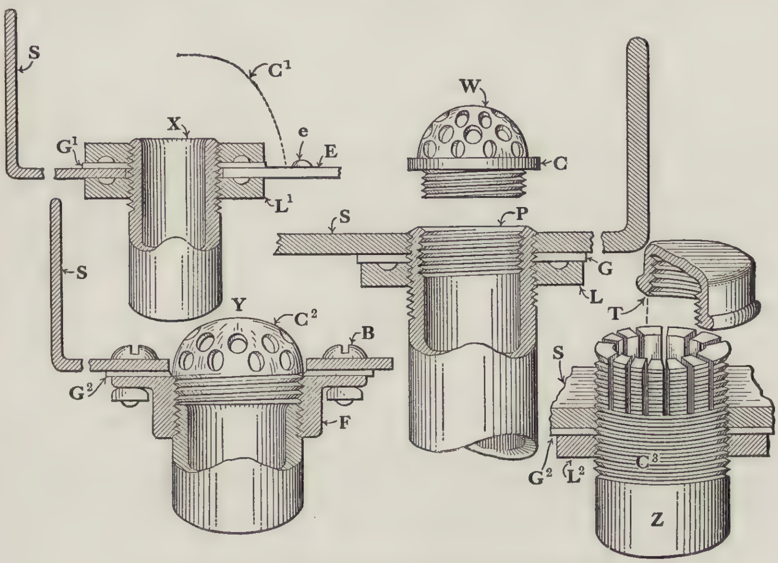


Fig. 50. Tank Safe Pan Drain Pipe Connections

copper gasket between two cloth gaskets soaked in red lead and oil and bedded on red lead putty; **G**^{1}, a wrought washer; **e**, solder attaching wire mesh to the copper gasket mentioned, and **C**^{1} a wire mesh hood soldered over the safe pipe to protect it from chance obstruction. The bottom of the safe for some distance around the hole should be bumped down (leaving the hole portion flat) so that the only water that will not readily run out at the pipe will be that filling the depression made around the hole.

Sketch **Y** shows a common pipe floor flange bolted to a safe pan. **S** is the safe; **F**, the flange; **G**^{2}, a gasket; **B**, bolts, and **C**^{2} a bee-hive strainer screwed into the flange. The flange is retapped by hand, from the back, sufficient to allow the strainer to screw in readily and

the safe pipe has a thread cut shorter than standard so it will not screw in deep enough to interfere with the strainer getting sufficient hold to keep it safely in place.

Sketch Z shows a safe pipe with a long-screw slotted at the end and screwed through far enough to take a pipe cap cover and yet leave the slots exposed in a way to answer as a strainer for the safe pipe. It is best to make this portion out of brass pipe so there will be no danger of rust closing the slots. The slots are made with a common hack saw by sawing 6 or more evenly spaced cuts in the end of the pipe. **S**, is the safe; **C^3** the slots; **T**, the cap; **G^2**, a gasket, and **L^2**, a locknut. If the pan is not heavy enough to tap, the strainer feature can be arranged by using the cap as a combination lock-nut and strainer. Screw the cap down tight on the long thread to be used and drill holes around it, through the head and on through the pipe; then unscrew the cap. When the pipe is placed, put a gasket and washer on and screw on the cap tight, leaving it so the two sets of holes match; then tighten the lock-nut below, using over it a gasket and washer also, if desired.

One corner of a sheet-lead tank safe is shown in Fig. 51, the corner seam being wiped up, the flange tacked down with 1-in. galvanized brads, the sides supported by rectangular strips chamfered on the inside top corner and toe-nailed to the floor. The lead safe pipe is wiped in as usual for similar connections, and a wire mesh hood soldered over the pipe connection. Dotted lines indicate the method of nailing the strips down. In cutting out the corners of the sheet lead, the side turn and flange are marked off to leave the bottom of proper dimensions and the sides cut parallel with the bottom lines as far as the chamfer turn, in line with the bottom line on one side and leaving a lap, if desired, on the other. Then, if the chamfer makes octagon corners, cut the gap flaring about 10 deg. from the miter line on each side, for the distance needed to cover the chamfered part. The top flange edges are then finished out by cutting parallel to the miter-line.

If a tank is supported by bolsters resting in a lead safe pan, they should have a generous bearing surface so as not to concentrate too much weight on a limited area of the lead.

Supply pipes are frequently incased in cast or wrought safe pipes so as to confine leakage and lead it to a point where the water can do little damage. Such pipes may lead only from the basement to the second story and there end, or may continue as a pipe or covered channel under a floor board over some particular apartment below. Such sometimes contain both supply lines and waste from the basement to a toilet room safe, by any course convenient to favor all essential conditions at the least cost. It is an unwritten law that

supplies in safes of any kind must be so installed that they can be removed for repairs or renewed by uncoupling and withdrawing through pockets or otherwise. Safe conduits are usually a fair frost protection if choked at the upper end to prevent air passing through.

In Fig. 52 are a number of examples of safe pipe supports and top and bottom connections. **A**, shows the bottom end of a cast pipe line, presumably terminating overhead in the basement, standing in the eye of a bar support. The bar is notched into cleats nailed on the side of the joists. Ring hangers of this character, with hubs on opposite sides tapped for rod or pipe can be purchased. With these, any suitable length of arm can be used. Cleats, nailed on joists and

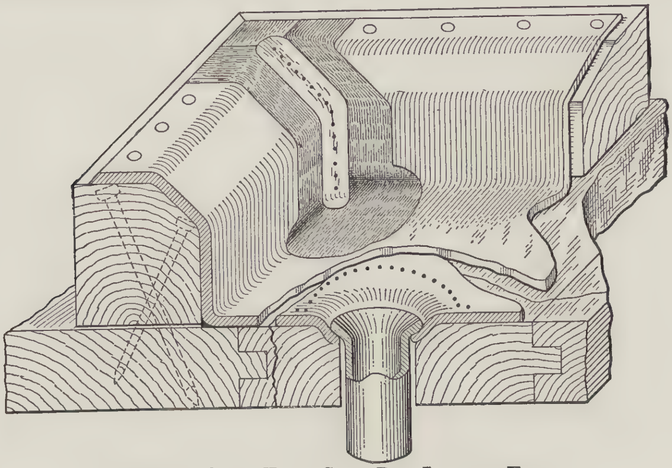


FIG. 51. LEAD TANK SAFE PAN LAID ON FLOOR

supporting a piece of 2×8 or 2×10, bored for the pipe to pass through, so the hub will catch on the shoulder, will also support a safe line. If desired, the hole can be bored countersunk and a plain pipe end stood in the hold instead of using a hub as shown.

B is the upper end of a cast line ending with a ferrule at the safe pan, as needed to join to a lead safe. Dotted line **S** is the pan bottom.

C shows a cast line terminating in a pocket, the pocket being sheet lead and the pipe from the hub, up, a long combination ferrule soldered or wiped into the pocket. The ferrule end is passed through a hole in the pocket bottom and soldered from within. Sometimes the top of a pocket is soldered on after the pipe is tested, but a better way is to make the top flange wide enough to make a return over the cover. Cut a piece of three-ply veneering to the size of the proposed cover,—lapping the flanges about ½-in. The edges of the pocket on two sides and one end can then be turned up like a pan and soldered at the corners in a way to make the pan part water-tight. The veneer can then be dropped in and the lead standing up worked down

over it and soldered at the two completed corners. The false cover may then be slipped out at the free end and a cover of galvanized iron or, sheet lead with stiffeners soldered on one side, cut to the same size and slipped into the run-ways formed by bending the lead over the veneer. The open end can then be folded over the cover to conform with the balance and soldered at the corners. There is no need for further precaution, but the cover may be puttied around if desired. Such pockets must be accessible. They are generally under floor, with boards screwed down above them.

Some thought must be given each job on the subject of pipe placing and removal before locating a pocket, and the plumber will make various provisions, to suit circumstances, too numerous to mention in detail. In the pocket **C** a brass solder nipple is wiped in the end shown; a trap screw is soldered opposite in the other end. The pocket ends may be soldered or wiped to the body, inside or outside, but are best made square and set on, thus placing the solder inside. The pocket may be made of galvanized iron if preferred. Lead pockets should be protected from rats by wire mesh, as indicated by the dotted line.

From the pocket to the toilet in the job shown, there is but one turn,—that made by the 3-way ell shown at **P**. The supply was lowered to the basement from the pocket. From the pocket to **P**, it was passed through the trap-screw and into the pipe. The supply ell was put in at the 3-wall ell. The balance (Sp.) was placed from the toilet room. The pipe can be taken out and renewed if necessary, in the same way. There is a plug at **P**,—it answers for inspection and is a means of removing the supply ell alone without breaking the safe pipe and without actually removing the supply pipe.

Sketch **D** indicates the foot end of a cast safe pipe supported by a tee with the branch hub cemented into a brick wall. This makes a good anchor if well done.

Sketch **E** illustrates the upper end of a wrought casing pipe for supply. There are usually several of these side by side, each taking care of a single pipe. Such casing confines and leads any leakage that may occur in that part of the supply; shows which pipe of a series concealed in a partition wall is leaking; protects the pipe from frost, and prevents contact between hot and cold lines. Lines of this kind are usually suspended by a cross board between the joists resting on cleats, the pipe hanging by a locknut, all about as shown. The safing may be continued horizontally by using a bushed cross having plugged top and side openings large enough to insert a supply ell.

Now and then vertical lead supplies are specified to be encased water-tight. In any but the way illustrated in Fig. 53 this would be a more or less serious proposition. Proper suspension, however, fulfills

every requirement regardless of the kind of safe pipe used,—cast or wrought is equally good, so far as placing the pipe is concerned. By partial suspension from different levels, all damaging tensile strain is removed; by keeping the supply in the middle of the safe (in an air wall) conduction has no chance to seriously chill the supply, and the heat of a hot service line is not vitiated; by fastening the suspension wires at the top the line can be easily withdrawn by cutting at the lower end. As

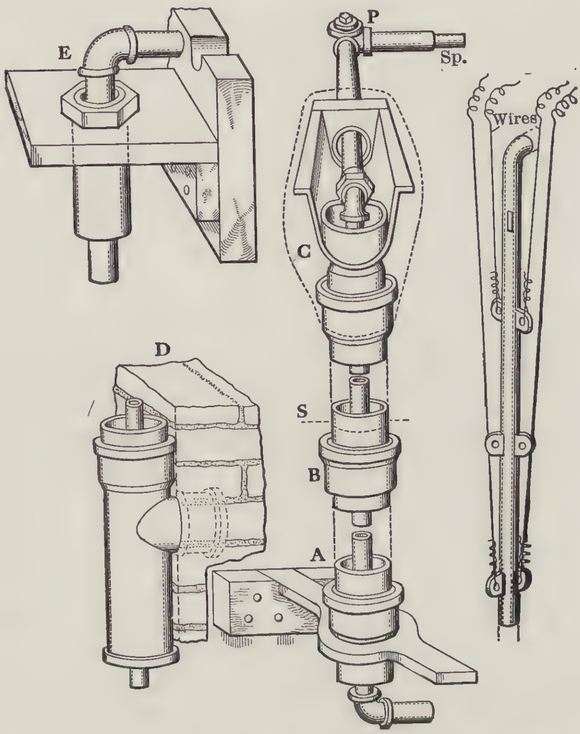


Fig. 52 Fig. 53

Fig. 52. Supply Safe Pipe Connections and Supports

Fig. 53. Lead Supply Ready to Lower Into Safe Pipe

seen in the sketch, the ears of lead tacks are soldered on in pairs radiating in four directions. This keeps the pipe from touching the casing. Suspension wires are fastened into the holes in the ears and the line lowered through the casing. The wires are then twisted around something, screws or nails, at the top, dividing the strain as equally as possible. Care must be taken to not have the spread of the tacks too great to go into the safe pipe easily. In some cases a heavy single suspension wire has been soldered at intervals to a line of lead pipe and the whole covered with felt before lowering.

CHAPTER XXII

Lead Lined House Tanks

Was it necessary to elect some particular kind of indoor overhead water storage tank for use in all inside tank jobs, the wood-case lead-lined type would be almost without exception the choice of the plumber for such comes nearer than any other to being universally suited to all practical conditions, has many peculiar advantages, and when properly erected and equipped presents few points that may justly be criticised adversely.

A lead-lined tank is constructed on the job; can be proportioned to suit the space available for it and needs no large hole or passageway by which to get it into place in the building. Being built up piece-meal, it requires no special rigging or power to set it. It weighs no more than other forms of tank of equal capacity that are likely to give anything like the same length of service. No expensive preparation for setting is necessary. The cost compares favorably with that of other forms of equal capacity and service. With any dimensions of practice, the amount of surface favoring deposition and retention of sediment is relatively large. The weight is ordinarily, without special care, better distributed over a larger area than is practical with cylindrical tanks without special provision. No safe pan for "sweating" is necessary because exterior sweating does not occur,—a result of the wood casing preventing air from circulating in contact with the lead. The favorable distribution of weight and deposition of sediment is due to the large flat bottom. The pressure is practically uniform and ever ready for any purpose as long as there is water in the tank,—this is true of any gravity feed tank. The length of service of a lead-lined tank may be taken as a life time. The repairs are usually slight,—a new bottom being the utmost necessary. Many tanks have served 25 years without requiring any repairing. These are some of the points in favor of lead-lined tanks. Facts that may truly be stated against them are:

The cold water gets warm in summer; if installed without frost packing or covering, some trouble is experienced with sheet ice in cold attics in cold climates; without proper protection, a valuable feature too often omitted, the water is likely to breed mosquitos in summer, and is open to attic dust and various chance contamination throughout the year; being overhead, damage from a leak is always possible unless there is a safe pan under the tank,—seldom placed unless the finish or decoration beneath is quite expensive; the pressure is limited to the gravity-head; lead linings are attacked by some waters, though fortunately those that

act on lead to an appreciable extent are so nearly included with the supplies not recommended for domestic use as to leave the lead-lined tank practically unrestricted in the field of service in which it is and will be almost altogether used.

Tank proportions for ordinary house service range from 5 ft. long by 3 ft. wide, to 8 ft. long by 4 ft. wide. A common size is 5 ft. by $3\frac{1}{2}$ ft., by 30 in. deep, made of $1\frac{3}{4}$-in. stuff screwed together, with one tie across the center of the length. This size is ordinarily taken as 300 gals. capacity with allowance made for the overflow margin. The length of a tank is the long side, the pieces for which are tenoned to receive the ends. End pieces for tanks $3\frac{1}{2}$ ft. wide should be at least $1\frac{3}{4}$ in. thick, finished, and such need no ties or stays when the tank is less than 3 ft. deep. Short side pieces may be $1\frac{1}{2}$-in. thick, finished. Tanks 6 to 8 ft. long inside should have side pieces at least $1\frac{3}{4}$-in. thick, finished, and should have two ties, each one-third of the way from the end. If a tank is more than 3 ft. deep, the ends should be tied in the center of the width if the width is 4 ft. out to out or more. If the outside width does not exceed 4 ft. and the depth is not over 4 ft., thicker end pieces may answer in place of a tie, but the tie is safest because deepening the tenons, as might then be necessary, to hold the ends against heavier pressure weakens the side pieces; if not deepened the ends may push out. If deepened, the side ties should bear nearer the ends; three side ties then become necessary, so nothing is saved by extra heavy end pieces. When a tank is deep and as much as 8 ft. long, place three side ties,—one in the center and one 15-in. from each end. Two side ties would do as well, if two draw rods are placed across at each end through the side pieces outside the ends pieces,—one near the top and one at the center of depth. Large washers, or, binding staves from rod to rod, should be used with such rods.

There are three reasons for making a house tank long one way and narrow the other. Small width avoids tying end-wise to prevent outward deflection of the ends; increased length distributes the weight over a greater number of supporting timbers and also gives capacity to make up for the narrowness without adding to the height. There are several reasons for making a tank shallow. In most roof spaces a low tank will go closer to the wall than a high one,—the closer to the wall the weight is, the stronger is the support; the lower the tank the less is the lateral pressure strain and the bracing is consequently cheaper, besides, with low height less spot-wiping is necessary to keep the side lining in place. It should be remembered that the lower a tank is the less is the effective depth for its height because the overflow margin depth does not decrease with the height and must be greater for tanks of large area because of the greater uncertainty as to probable amount of shrinkage and settlement. Both extremely high and low lined tanks are therefore

to be avoided. Very low heights are expensive because of the high percentage of non-effective depth, especially so where the overflow must be large to take care of a rapid incoming supply.

A tank bottom should be the full size of the tank's outside dimensions and may be nailed *on* as there is no strain tending to pull it off. The sides should be screwed to the ends unless there are tie rods at the tenons or ties across the length near the ends. A mission of the wood walls is to keep air from passing over the exterior lead surface, so the cracks must be well jointed. Feather strips in grooves, like shown by detail **a**, in **A**, Fig. 55, are better for thick planks than tongue and groove joints. All timber for a tank should be sized.

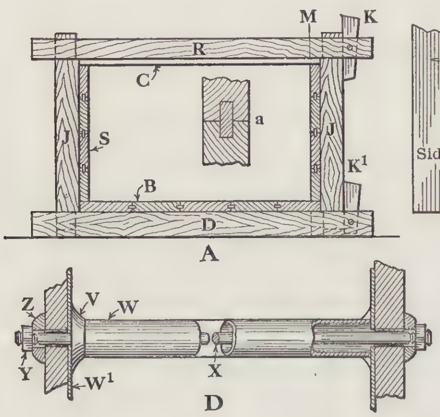


FIG. 55. LEAD-LINED TANK CASE CONSTRUCTION

Sketch **A**, Fig. 55, is a cross-section of wood casing showing a set of stays in place. **B**, is the bottom; **S**, sides; **C**, cover,—covered with the metal on under side, or bare, according to construction; **R**, a wood girder equivalent to a tie rod; **D**, same as **R**,—being under the tank, **D** may also serve as a piece of the supporting dunnage; **J**, "buck-staves," preventing tank sides from springing out; **K**, $\mathbf{K}^1$, wood keys or wedges for keying the staves against the tank sides. A screw through the tie timber to the key is used to prevent the key from slipping up and thus unkeying the stays. When stay **D** rests on a floor, the key, $\mathbf{K}^1$, and tenon on **J** must be short enough not to bear on the floor. The dunnage pieces, including ties **D**, may be 12, 15, 18 or even 24-in. apart, according to depth of tank and thickness of bottom. A bottom is usually made of the same stuff as the sides. The ties **D** and **R**, and dunnage, may range from 4×4 to 6×6-in., according to the size of the tank. The depth is necessary in these pieces to give adequate compression surfaces and general strength to the mortise and tenon, the tenon ranging from 1 to 1.75 in. thick. A gib and key may be used in a mortise with parallel

end walls, if desired. The key alone, as shown, seating against an oblique wall that tapers the mortise to equal the taper of the key is simpler. The mortised holes in the ties should be separated to equal the width of tank, out to out, less the thickness of one wall, as indicated by **M** in sketch **A**. In sketch **C**, the mortise, **N**, tenon, **T**, and key, **K**^{1}, are shown separately in detail. It is a good idea to put one or two $\frac{1}{4}$-in. bolts through the tie from side to side between the mortise and end, as indicated in sketch **C**, to prevent any chance of the wedge wall of mortise pushing out.

Sketch **B** shows an end piece tenoned into a side piece. The gain or notch in the side is generally made $\frac{1}{2}$ in. deep, with width to give a tight fit for the end-piece thickness. The ends should enter the side pieces from 2 to 4 in. from the ends, according to the depth of tank,—2 in. being usual for tanks 2 ft. deep.

The width of tank wall pieces should never exceed 10 in., and are better, if narrower, so far as shrinkage and swellage is concerned.

If the height of tank space prohibits using the kind of ties shown in sketch **A**, tie rods, like shown in sketch **D**, passed through the tank and isolated from the water by lead pipe casing can be substituted. The pipe casing bore needs to be only large enough to slip the rod through. Two nuts to the rod instead of a head and one nut are best. A long stiff hard wood block crossing one plank and a portion of one or two others may be placed behind each washer to extend the pull of the rod. Near the bottom of the top plank or top of the second plank is usually the best height for a rod unless the tank is deep and two rods, one above the other, are used, in which case a stave from one rod to the other can be used under the washers.

In sketch **D**, **V** is a flange joint fixing the rod casing to the tank lining; **W**, the lead pipe casing; **W**^{1}, tank lining; **X**, rod; **Y**, nut; **Z**, washer. Rod ties of this type may be located so that each will take the place of one pair of spots or "bull-eyes." With such the top of the tank is free so that cover and trap-door may be arranged in the manner most convenient.

Fig. 56 illustrates a section of tank lining without the casing, the various pipes of ordinary service and sundry other features being drawn or dotted in. The letter **O**, represents the overflow; **T**, tell-tale; **R**, relief pipe admitting air to house supply **S**, so when cock is turned, supply will drain; **V**, relief pipe from hot water storage tank in kitchen, providing an *always-open* relief for vapor and steam that might produce disastrous results in a tank job, if no *unclosable* vent was provided,—all rising fixture-feeding lines may be and often are continued to the tank in this way to provide automatic inlet and outlet of air and vapor, as needed.

S^1 is also a house supply,—**C. V.** being a cistern valve, with weighted plunger; **G**, its seating washer; and **L**, its hollow plunger stem admitting

air at the top to the supply line, thus serving the same purpose for S^1 as pipe **R** does for **S**. The cistern valve and its pipe is shown merely as an alternative and better way of taking the supply from a tank than is the stop-cock arrangement at **S**. An inverted stop and waste cock with lead tubing soldered on at the waste hole is sometimes used at a tank outlet,—this drains the supply to a higher point, but neither the stop shown, nor the inverted stop and waste is as good as the valve arrangement shown. A scheme superior to all of them is a standing bath waste taking the water through a gauze at the waste inlet. The overflow holes must be above the tank overflow level. The supply is then always open to the atmosphere, there is no danger of disarrangement and the valve wire can be attached to the stand pipe as a means of opening and closing the supply from down stairs. When the head room above a tank is low a pulley instead of a bell-crank should be used over the valve in order to obtain a straight line pull.

P is the supply from pump to tank. It may be carried up through or outside of the tank and should discharge over the water. A tank supply should never enter the bottom and end there, as is sometimes done in order to use the pump discharge to the tank as a distributing main for cold water fixture supplies. It is slightly easier to pump against the actual head of water than to always lift the supply above the overflow line, and one line of pipe is saved when the delivery is entered at the bottom for a down-feed. But, a leaking check may thus empty the tank at any time, without warning, and cutting off the house supply for any purpose precludes pumping into the tank at all, while trouble at the pump may put the whole job out of commission and trouble with a fixture may prohibit independent service of the pump.

House supplies should project up in the tank at least 1-in. so quite a layer of sediment may collect on the bottom without entering the pipe in case cleansing of the tank is not regularly attended to. The pipe leaving a tank should be covered with a wire mesh to protect the supply and valve seats from leaves or other foreign substances. The mesh over a cistern valve should be removable so that repairs can be made without extra work. For this reason the mesh shown at **X** in Fig. 56, is wired down to loops soldered to the lining. It is best to take the tell-tale pipe from the bottom of the overflow, as shown. Otherwise, if it is far from the overflow, settlement, shrinkage, original false leveling or all combined, may cause waste at the overflow without warning through the tell-tale. The tell-tale pipe should end over a sink or other fixture where the person attending to the pumping will heed its discharge.

In country districts the air is not loaded with soot and other impurities as is city air, and house roofs are comparatively clean. Water led directly from a country roof into storage tank is therefore in fairly good condition. For this reason many country jobs, where the roof

levels are favorable, have extra large tanks, into which a portion of the roof water is dropped directly in order to save pumping. This, also, indirectly, has the effect of increasing the general storage capacity, for the cisterns are not called upon for the water deposited directly into the tank,—an item of some importance where the roof drainage far exceeds the storage capacity, especially in jobs with two tanks devoting one exclusively to the culinary and drinking supply.

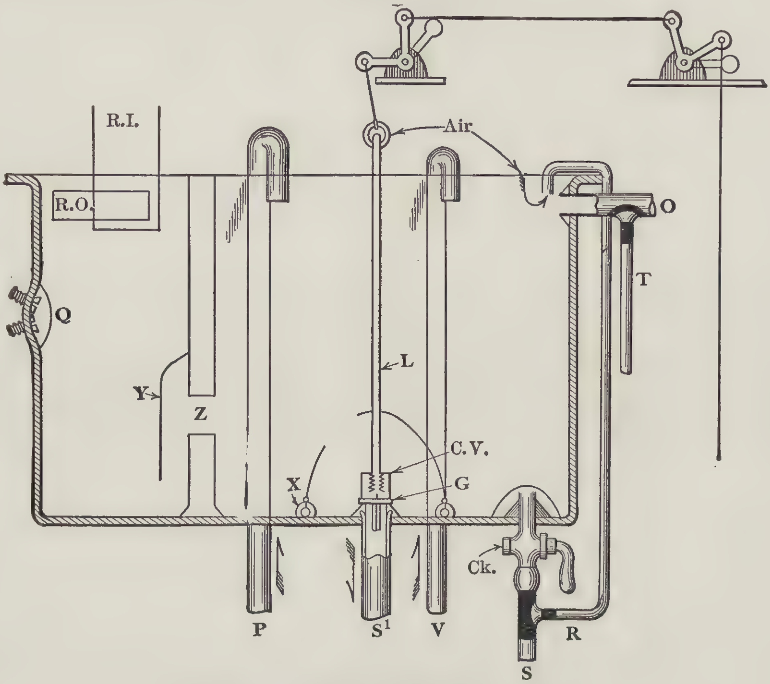


FIG. 56. LEAD-LINED TANK CONNECTIONS

In a one tank job, tak:ng part of its supply direct from the roof, a partition is put in as shown by dotted line in Fig. 56. A hole (**Z**) is left in the partition for water to pass through into the main compartment. The hole is generally placed a little lower than **Z** shows, say 6-in. above the bottom. It should be at least 1½ times the size of the lead pipe from the roof and should have a protecting hood, **Y**. The hood should be solid to a little below the level of the bottom of hole **Z**, and may extend from there to the bottom of the tank in the form of wire mesh,—leaves, twigs or other foreign matter entering the tank by chance cannot then drift directly through **Z**, not float up and through it into the main tank. The roof inlet is marked **R.I.** The roof water overflow **R.O.**, discharging to some lower portion of the roof, should be 1½ times the area of **R.I.** Both the inlet and overflow should be protected at the roof line by wire mesh to prevent birds from entering.

A "bull-eye" anchor or spot like placed at regular intervals in tanks, over 30 in. deep, to help hold the lining in place is shown at **Q**. If a tank is 3 ft. deep, one ring of spots 15 to 18 in. apart is spaced around at mid-depth, keeping 12 in. or so away from the corner seams. About the same area of lead unsupported otherwise may be allowed per spot for other greater depths. For two rows of spots, stagger them so one set comes under the spaces of the other, placing the full row above. This brings the one spot short down to where the bottom helps to resist sagging. A 42-in. depth with two rows of spots would ordinarily have the lower row 15-in. up and the full row $28\frac{1}{2}$-in. from the bottom. For these spots the wood of the casing is scooped out regularly, like the segment of a sphere, to $\frac{3}{4}$ or $\frac{7}{8}$-in. deep by 3-in. diameter. The lead lining when otherwise finished is dummied into these depressions and soiled and cleaned ready for wiping. Three screws, generally $\frac{7}{8}$-in. No. 11, are then run through the lead into the wood in each spot, diverging at the points. The countersink of the heads is allowed to project for solder to fill in behind, all somewhat as indicated at **Q**. Care must be taken to put the screws into the deeper part of the depression where a safe depth of solder will cover them without wiping a high crown spot. The top flanges of linings are nailed down with 1 to $1\frac{1}{4}$-in. tinned brads; the seam edges are tacked in with 1-in. or shorter tinned or copper brads, partly to hold the lead in place permanently and partly to prevent it raising and buckling too much under heat while wiping the seams. The lighest lead suitable for house tanks is 4-lb. per sq. ft.

CHAPTER XXIII

"Closed" Storage Tanks

"Closed" attic tanks are not literally closed to tne atmosphere,—they are usually plain or galvanized iron cylinders, open to the air through the overflow and tell-tale, both of which should be well protected from the entrance of vermin. The tanks should have a manhole to make cleansing easy. If of plain iron it should be coated with hot asphalt inside and out. A safe pan with waste pipe is necessary to take care of sweating drippage. The tank is set on bolsters as indicated in Figs. 57 and 58. Whether the bolsters rest upon the safe pan or upon a set of sleepers depends upon which way the building supports under the tank run; if the length of the tank crosses the building timbers, the sleepers are generally necessary to distribute the weight of the tank and water over as many beams as possible and the tank ought to be placed close to or over a wall or columns.

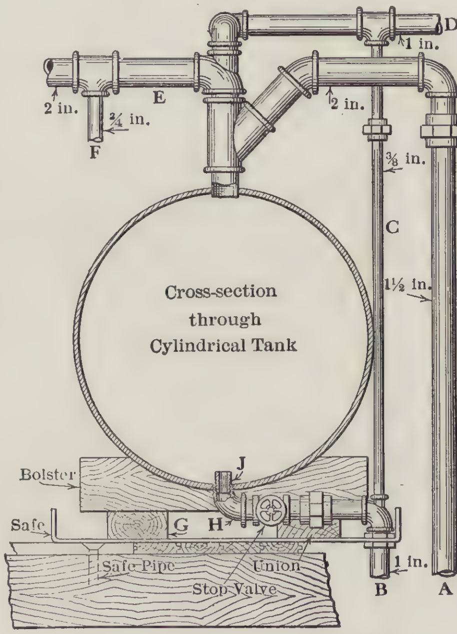


FIG. 57. CLOSED ATTIC STORAGE TANK

The principal merits of the closed tank are that it keeps dust and insects out of the water, prevents damage by accidental overflow, and, there being no water surface freely open to the air, there is no chance for mosquitos to breed in the water in warm weather.

Fig. 57 is arranged for pump delivery. **A**, is the pipe from pump; **B**, supply to house tank; **C**, relief to allow house supply to drain; **D**, vapor pipe direct from kitchen tank,—the hot lines extensions may also be connected into **D**; **E**, overflow pipe; **F**, tell-tale pipe; **G**, support sleepers; **H**, service ell,—tapped inside on male end and screwed into tank bottom; **J**, sediment extension of house supply,—screwed into service ell. The sizes of these pipes for an ordinary job are marked on the sketch. The connection for the pump inlet water is Y-ed up and made large, as shown, so the water of each stroke will have time and

room to flow into the tank between pump strokes without wasting out at the overflow opening.

High pressure service directly connected to the fixtures is often a great disadvantage, especially if the water is not very clean. Therefore to avoid using special faucets, large air chambers, extra heavy kitchen tanks, high pressure closet tank valves, etc., and to take out much of the suspended matter that may be carried by the high velocities of strong pressure, the high pressure line is often piped to an attic tank and the job proper fed by gravity under the low pressure due to the height of the tank.

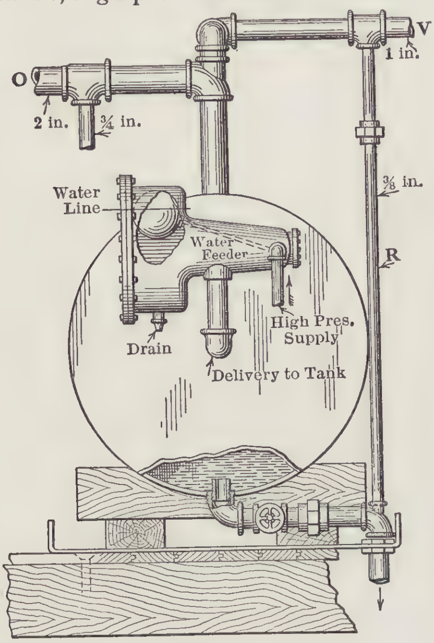


Fig. 58. Automatic High Pressure Feed to a *Closed* Gravity Feed Attic Tank

Open lined tanks are as a rule fitted with a large ball cock on the high pressure supply so the tank will be kept full without attention. The same may be done with a "closed" tank, but an exterior water feeder located so as to maintain the proper water level is often used instead and is much more convenient where the water is clean and the tank man-hole does not therefore have to be opened often for cleansing. A ball-cock water-feeder like used with low-pressure steam heating boilers answers. Fig. 58 shows such a feeder connected. The pipe connections are simpler than for pump delivery. **O**, is the overflow; **R**, relief to house supply, and **V**, vapor relief from kitchen tank.

CHAPTER XXIV

Pneumatic Pressure Water Service

The problem of size tank and comparative service is raised as often as pneumatic work is contemplated, yet, not allowing fully for the space required for air nor appreciating the pressure one would be regularly required to pump against has led many to order smaller tanks than would again be allowed in the same job. A general understanding of the elements of pneumatic service will remove the cause for what little disappointment has attended its use and result in still more general employment of this form of pressure. Catalogues do not contain much of the data needed to reach a conclusion in the best interests of all, as fitting the job to local conditions is within the province of the plumber and has been largely left to him by the makers. So far as the trade is concerned the result has been fairly good, but there is a heavy demand from country town merchants and house-owners in rural districts, from which is derived most of the orders from people of little or no experience. These orders generally reach the jobber, not the fitter, and, finding no fitter in the locality to refer the order to, it is generally up to him to estimate the conditions and fill the order accordingly. Knowing the effect of possible strains in general handling and transporting of large tanks and the likelihood of trouble from any but the simplest efficient outfit, the smallest plain cylinder that will answer, heavy enough to safely stand shipping, a good pump, a glass water gauge, with valves; a check valve, a globe or gate valve, a drain cock,—possibly a water pressure gauge without pig-tail, and such other fittings and pipe as was ordered or is known to be needed usually constitutes the shipment. The tank has one or two holes (turned down when setting) for pump water to enter and house supply to issue from.

No holes are made in the air zone for fear that poor fitting will thus result in air leakage. If water absorbs some of the air there are thus but two ways to replenish it,—through the drain when tank is *empty* or by pumping water and air together into the tank. Some makers provide for raising the pressure, above simple compression of the initial air, by the latter method. If the pump furnished is simply a good water pump, it may or may not do well under the admission of air with the suction water, because the form of space between plunger and discharge valve may cut down the capacity of the pump through repeated re-expansion of the air it cannot expel. This is one source of trouble from the assembled-from-stock outfit. If the water is not suited for a plain iron or steel cylinder, it soon has a disagreeable taste and the fixtures

become stained; if the tank is too small for the duty, either too frequent or hard pumping results. If light weight, poor quality, or any of the fit-the-job-to-the-price elements are present, the service will, of course, be according.

Fig. 60 is a typical cottage outfit consisting of the items mentioned in the foregoing specifications, erected on the basement floor. Scalloped wood blocks answer for shoes or pillars to support the tank high enough

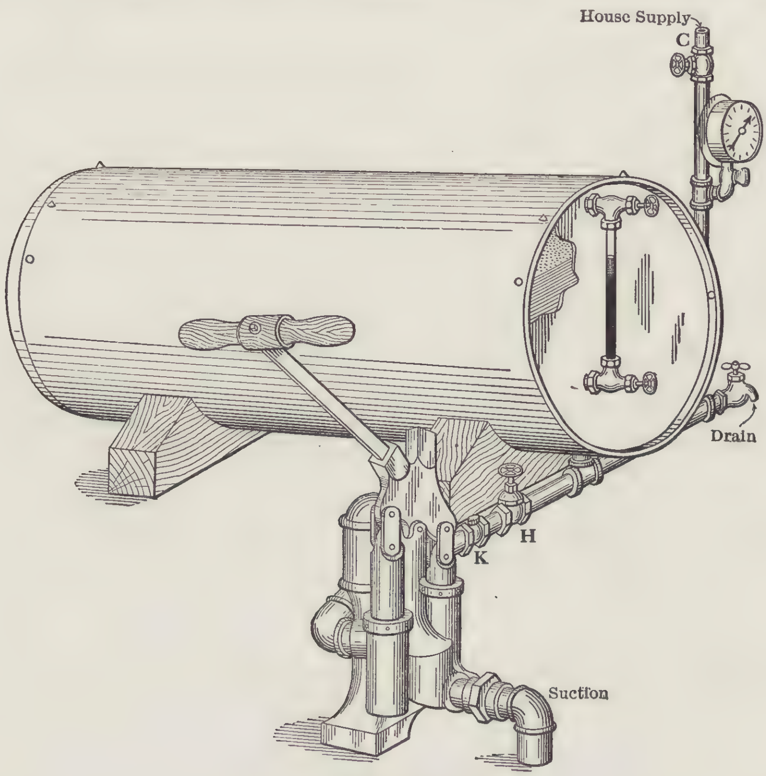


FIG. 60. TYPICAL COTTAGE OUTFIT

for pipe connections. **K**, is a check valve to retain tank water and to supplement the pump check; **H**, controls the tank water when necessary to open the check or break the pipe connection; **C**, is a stop and waste valve,—a stop and waste cock or two valves will answer; the drain faucet may answer for drawing in basement,—a cock or valve, open or connected to a drain pipe will answer for the drain; the glass water gauge shows the height of water, from which the pressure and contents may be figured,—if the glass leaks or breaks, its valves are used to close the openings. The pressure gauge may be one that reads in feet altitude to which the water will rise, pounds pressure per square inch, or both,—it serves as a guide when the glass gauge is out of order, and for com-

paring pounds pressure with corresponding heights of water in the tank. Users often mark or cut the "pounds pressure" on the tank head to correspond with the water heights shown by the glass gauge. Such marks are reliable only for heights and pressures resulting from compressing the initial quantity (empty tank full) of air from atmosphere to the pressures and altitudes indicated. The pressure gauge alone is indicative of true pressure if air has been pumped in either with the suction water or into the air zone by independent air pump. Pressures deducted for simple compression from water gauge altitudes are also misleading to whatever extent the initial air may have been absorbed by water.

The pump shown is double acting. To take the house supply from a separate opening would be better if there can be said to be any practical difference. Whether there is depends much upon the amount of sediment in the water; whether the tank "falls" toward or from the house outlet and whether the tank is plain or galvanized. A tank should pitch slightly away from the house outlet, and there should be a hand-hole or man-hole for cleansing purposes. Galvanized tanks give cleaner water and seldom cause trouble from seam or rivet leakage.

No definite value, for general application, can be assigned to the merits and demerits of the two systems, but a basis for preference of on or the other for an individual job may be established by contrasting elevated tank service with that to be obtained from a pneumatic outfit working under the same conditions. Let us suppose Fig. 60 to meet the requirements of an ordinary family living in a one-story cottage; that hand-pumping and cistern supply of roof water both operate to produce economical consumption; that 50 gals. consumption per day were estimated and that the tank is 500 gals. capacity and intended to be pumped up about once a week, depending somewhat on usage and pressure carried. How does its service compare with that which would be obtained from an attic tank in the same house, presuming the price of the pneumatic outfit would place a 500 gal. tank in the attic?

Elements of the Elevated Tank Job: The water would have to be raised about 19 ft. 500×19 equals roughly 79000 ft.-lbs. lift to fill the tank. Service:—all the water delivered by gravity to any point below the tank, at uniform pressure equal to the static head, at points of usage, not exceeding 8 lbs. per sq. in. at any point not below basement faucet level. Possible risks and annoyances from attic tank: frost damage, leakage, overhead weight, "warm" cold water in summer, absence of high pressure for any purpose, and, mosquito breeding in warm weather, if the tank is open style.

Elements of the Pneumatic Tank Job: 500 gal. tank pumped $\frac{2}{3}$ full, producing 29.8 lbs. maximum gauge pressure with 333 gals. of water to work on, available under a sliding scale of pressures ranging from 29.8

to 0. 333×8.3 equals 2764 lb. moved (pumped) (assuming a head equal to the mean pressure of 28.9 and 0) against an equivalent head of about 34½ ft., equalling, say 95000 ft.-lbs. 166 gals. would be expelled before the pressure fell to 7.5 lbs. gauge pressure, nearly all of which would reach *second floor* fixtures. 65 gals. more would be expelled before the pressure fell to 3.7 lb. gauge, all of which would reach first floor fixtures. The balance ($\frac{1}{5}$ total tank capacity) could be drawn in basement, if needed, but is best looked upon as a permanent residual maintained to create its corresponding pressure in behalf of better service from the upper portion of the tank. The residual $\frac{1}{5}$ (about 100 gals. in this case, according to depth of basement) needs to be pumped but once, of course.

In this particular case the labor of pumping up appears to be about 22 per cent. greater for the pneumatic outfit, in order to make available something less than half of the tank's capacity, than it would be for the elevated tank, of which the entire contents would be available under the limitations before mentioned. Which of the two jobs one might prefer would have to be determined by the individual according to local value of the service mentioned above for the elevated tank, and that which follows. Pneumatic tank Service: Cheap permanent support; cool water in summer; immunity from freezing in winter; no water surface open to the air; least possible damage from leakage; a limited quantity of water at any pressure desired available some of the time. Drawbacks: the limited quantity of water ready to use at any time from approximately equal investment; frequency of "pumping up"; extra work and wear and tear on pump.

In small work, pneumatic pressure storage tanks, always cylindrical, are frequently stood on end to save room. In this position, the percentage of water filling by depth, always agrees with the actual contents by measure,—that is, an inch rise or fall represents the same number of gallons regardless of the stage of water. This is so far from true in all but just half full, when a cylinder is placed horizontal, that a comparison of the water segments and air zones at different stages of "full" will be welcomed by many.

In Fig. 61 seven water heights ranging from $\frac{1}{5}$ to $\frac{4}{5}$ of the diameter are represented by the chords, with reference letters, the fractions being set at the left of diagram. In the right half of diagram, chords are indicated marking similar fractions by area, the fractions being set opposite, at the right of the diagram. The difference between segmental water areas contained in segments marked by chords at equal fractions of depth on the diameter is greatest in the smallest segment less than half, as **ABY**. Likewise it is greatest in the largest segment more than half, as $\frac{4}{5}$, **A′B′Y**, because the water segment at $\frac{1}{5}$ full is equivalent in area to the air zone at $\frac{4}{5}$, full,—all water segments and air zones divided

at half or less, being reversed into corresponding zones and segments divided at half or more by mere inversion and change of terms. This makes it unnecessary to really figure any but the water segments less than half.

Table XX. Pneumatic Pressure Service—Horizontal Cylinder. Approximate Data Applicable to Any Size of Cylinder

When the Depth of Contents Equals the Fraction of Diameter Indicated

Diagram Reference Letters	Filled to	Depth of Contents per cent. of Diameter	Water Segment per cent. of Cross-Section Area	Air Zone per cent. of Cross-Section Area	Pounds Pressure	
					Absolute	Gauge
A′–B′	$\frac{4}{5}$ full	80	85	15	97	82.3
C′–D′	$\frac{3}{4}$ full	75	81	19	77.3	62.6
E′–F′	$\frac{2}{3}$ full	66	70	30	48.9	34.2
Z	$\frac{1}{2}$ full	50	50	50	29.4	14.7
E–F	$\frac{1}{3}$ full	33	30	70	21	6.3
C–D	$\frac{1}{4}$ full	25	19	81	18	3.4
A–B	$\frac{1}{5}$ full	20	15	85	17.3	2.6

When the Contents Actually Equal the Fractional Capacity Indicated

Filled to*	Depth of contents per cent. of diameter	Water segment per cent. of cross-section area	Air zone per cent. of cross-section area	Pounds pressure	
				Absolute	Gauge
$\frac{4}{5}$ full	74	80	20	73.5	58.8
$\frac{3}{4}$ full	70	75	25	58.8	44.1
$\frac{2}{3}$ full	64	66	33	44.5	29.8
$\frac{1}{2}$ full	50	50	50	29.4	14.7
$\frac{1}{3}$ full	36	33	66	22.2	7 5
$\frac{1}{4}$ full	30	25	75	19.5	4.8
$\frac{1}{5}$ full	26	20	80	18.4	3.7

* Should the air space be reduced to $\frac{1}{8}$, $\frac{1}{16}$ and $\frac{1}{32}$ by pumping in water to fill successively to $\frac{7}{8}$, $\frac{15}{16}$ and $\frac{31}{32}$ full, the initial air would raise the gauge pressure to 102.9 lb. for $\frac{1}{8}$ space, 220.5 lb. for $\frac{1}{16}$ space, and to 455.7 lb. for $\frac{1}{32}$ space,—the original space being 1.0 of course, and beginning at atmosphere.

In Table XX following, the percentages of depth on diameter, areas of water segments and air zones, and absolute and gauge pressure are approximated for the fractions shown on the diagram in Fig. 61.

Simple compression is depended upon in the majority of pneumatic jobs, and one must look to its results in estimating the service. The middle $\frac{1}{3}$, by area, of a horizontal cylinder, is contained in a zone of about 28 per cent. depth, measured on the diameter; the middle $\frac{1}{3}$, by depth, measured on the diameter, embraces a zone containing about 40 per cent. of the total cross-sectional area. Below this zone very little water can ordinarily be counted upon at second floor faucets. By comparing the areas and pressures given in the table with the heads of water required in common dwellings, it will be seen that with the ordinary outfit working under average conditions, about 35 per cent. of the total area of the storage tank measures the water available for houses with 3rd story fixtures; 42 per cent. for houses with no fixtures above second floor, and 50 to 55 per cent. for cottages with no fixtures above the ground floor. This is assuming, of course, that it will be

considered time to "pump up" again when upper floor fixtures are out of commission for lack of water. Greater areas are made available for high fixtures both by higher compression of the initial air and by introducing air to raise the pressure. High compression of initial air gains by increased area in the maximum water segment. Introducing air prolongs the service to high fixtures by utilizing more of the water at low stages and may, according to pressure, so lift much of the water ordinarily standing as dead residual. "Residual" is not to be understood as never touched, like the permanent pig stock in a foundry yard. The unusable quantity (not lifted to service) of either simple or augmented com-

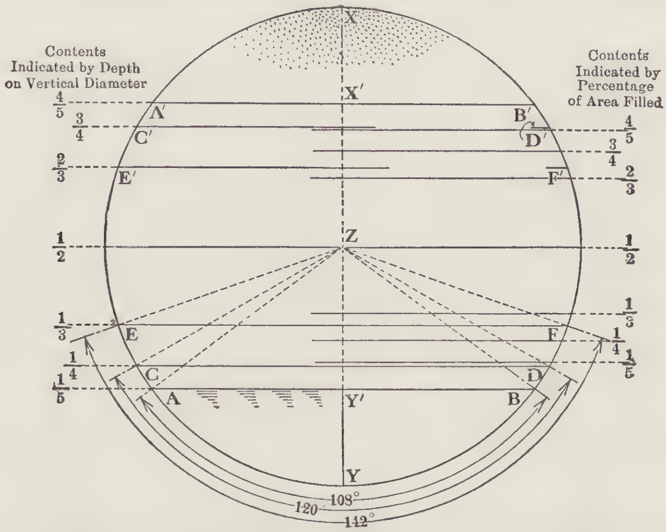


Fig. 61. End Section of Horizontal Pneumatic Pressure and Water Storage Cylinder Indicating Relative Capacities of Water Segments and Air Zones by Depths and Areas

pression is replaced to some degree by mingling at each "pumping up."

In estimating capacities with a view to determining size of tank, the data in the table is equally applicable to all diameters. The circle of Fig. 61 from which the figures were produced, was 10-in. diameter,—the percentages and pressures derived from it would be the same for a diameter of 10 ft. or any other size. With a tank in service before one, the data for an off hand estimate of contents is easily produced,—the depth of water is evident; the width of surface (chord), and the arc submerged can be approximated close enough. Suppose the water level to be **CD**, Fig. 61. The arc submerged is to the balance of the circumference as the area of its sector (**ZCYD**) is to the area of the whole cross-section.

Stepping the indicated width of wet surface around the circumference of the tank would show the submerged arc to be about $\frac{1}{3}$, or 120 deg. The area of the sector may therefore be assumed to be $\frac{1}{3}$ of the area of

the tank's cross-section. Depth of water subtracted from the radius leaves the height of the section triangle. Half the base (chord, or water surface on this case) multiplied by the vertical height, or, the whole base by half the vertical height, gives the area of any triangle. Find the area of the sector triangle (**ZCD**) and subtract it from the area of the sector; the remainder is the area of the water segment, from which the water contents are easily deduced.

For more accurate results from figures alone the common arithmetic rule for areas of segments will be found too long and tedious. The author prefers to, and thinks others would, make limited use of a table of natural functions of angles. Only the sines and cosines to even degrees are necessary and these are contained in Table VIII.

For an example, take the water depth at $\frac{1}{5}$, marked by **AB** in diagram Fig. 61. The radii of the sector (**ZAYB**) includes, say 108 deg., as shown. Half the angle would be 54 deg.; **Y′B** is its *sine* (half the chord or water-surface width); **Y′Z**, its *cosine* (height of the sector triangle); **Y′Y**, its *versed sine* (depth of water or height of arc). Then, remember: (a) *Sine* of half the angle (54 deg. in this case) multiplied by the *radius* and by 2 equals the *chord* (water-surface width in this case); (b) *Sine* multiplied by the *radius* and then by the *cosine* after it (cosine) has been multiplied by the radius equals the area of the *sector triangle* (**ZAB**); (c) area of sector triangle subtracted from the area of the sector (**ZAYB**) leaves the area of the water segment (**AYB**); (d) area of the sector (**ZAYB**) is to the balance of the circle's area (**ZAXB**) as the degrees included by the sector radii; (108 deg. in this case) are to 360; (e) *cosine* (**Y′Z**) subtracted from the *radius* (**ZY**) leaves the *versed sine* (**Y′Y**,—water depth),—*versed sine* is not given in most tables; (f) *sines* and other functions as given in tables are at unity and must first (before otherwise employing them) be raised to the dimensions of the work in hand by multiplying by the *radius*, in inches and fractions, or by feet and fractions, according as best suits the purpose; (g) that these reminders apply to every degree of the quadrant regardless of the size of the circle.

Application of the foregoing in determining the area of diagram segment **AYB**: Circle area 78.54; degrees in sector arc, 108; 108÷78.54 =30 per cent.; 30 per cent. of 78.54=23.56 in. sector area; sine of 54 deg. equals 0.809; 0.809×5 (radius)=4.04; cosine of 54 deg. equals 0.587; 0.587×5=2.93; 2.93×4.04=11.83 sq. in. in sector triangle; 23.56—11.83=11.73 sq. in. area in water segment **ABY**. The degrees shown give a depth of 2.06, proving the diagram laid out with a small protractor to be not absolutely correct. 2.06 is found by subtracting the cosine, 0.587×5=2.935, from the radius. 78.54—11.73=66.81 sq. ins. area in the corresponding air zone **ABX**. 11.73÷78.54 shows the water segment area is nearly 15 per cent. of cross-section area.

Suppose it is desired to find the water contents of a tank showing, by glass water gauge to be $\frac{1}{3}$ full, *by depth.* The area of the water segment can be found near enough for practical purposes, as follows: subtract the *depth* from the *radius*, thus leaving the *cosine*, at dimensions, of half the angle included by the radii of the sector; divide this remainder (cosine) by the radius to reduce the *cosine* to unity; then find the *degrees* of half the angle by taking from the table the degree set opposite the nearest *cosine* so found. Having thus found the degrees of half the angle measuring the chord, proceed as before. Using the diagram radius for convenience and working from the beginning, the solution would be: with $\frac{1}{3}$ depth taken as 3.31: 5.0 (radius)—3.31 = 1.69; 1.69 ÷ 5.0 = 0.33, the cosine sought. The nearest natural cosine to this, in an ordinary table, falls at about 70$\frac{3}{4}$ deg., say 71 deg. (142 deg. for the whole angle, as shown). Cosine of 71 deg. is 0.325; 0.325 × 5.0 = 1.62; sine of 71 deg. is 0.945; 0.945 × 5.0 = 4.72; 4.72 × 1.62 = 7.64 sq. in. the area of sector triangle. A sector of 142 deg. occupies practically 40 per cent. of the circle,—360 deg. Hence 40 per cent. of 78.54, about 31 sq. in., equals the sector area; 31.0—7.64 = 23.36 sq. in., approximately the area of the water segment, which by the length of tank, in inches, and divided by 231 gives the water contents in U. S. gallons.

The pressures developed by compressing air from atmosphere as is done in most pneumatic jobs, conform closely to Boyle's law for compression of fluids,—that the product of the pressure and volume is a constant quantity when the fluid is kept at constant temperature. 97-lb. absolute is given in the table as the pressure resulting from compressing air at atmosphere to 15 per cent. of its original bulk,—into a zone of $\frac{1}{5}$ height measured on the diameter, according to the diagram. Using the diagram circle area again to illustrate, the original volume may be considered as the cross-section area,—78.54; the air zone 11.72 equals about 15 per cent. 100 (per cent.) ÷ 15 = 6.6. The original pressure (atmospheric) equals 14.7 lbs. absolute; 14.7 × 6.6 = 97.02,—the absolute pressure recorded in the table as resulting from squeezing a volume of air at 1 atmosphere into 15 per cent. of the original bulk. Any absolute pressure resulting from simple compression, multiplied by the per cent. of original space into which the volume has been compressed will give the constant quantity, 14.7 lbs.,—the original atmospheric pressure. The per cent. of original space air has been compressed into, divided into 100 derives a quotient which, multiplied by 14.7 produces the absolute pressure corresponding to that degree of compression. 14.7 lb. of the absolute pressure does not register on a common pressure gauge. This is why the gauge pressures are also given in the table,—beginning with 97 lbs. absolute for 97.02, minus 14.7 = 82.3 lb. gauge pressure, as seen at the head of the column of pressure in the upper table.

The whole question of pressures will be more easily understood from

a homely comparison: One square inch of the atmosphere from sea level to its utmost height weighs, at 60 deg. F. and 30-in. mercury barometer, 14.7 lbs. Absolute pressure readings include this (free air everywhere exerts it, according to altitude) but common pressure gauges are not made to register it,—they are sensible of and manifest only the pressures exceeding atmosphere. One pound gauge pressure is therefore really 15.7, or in round numbers, 16 lb. absolute. Now suppose a flexible or telescoping cylinder holding 1-gal. could be fitted together air-tight,—ordinary atmospheric pressure (14.7 lb.) would exist within it, the same as outside of it. Then, if the cylinder be telescoped to $\frac{4}{5}$ gal., the pressure would rise, roughly, to 18.4 lb. ab.,—3.7 lb. g.; further telescoped, to $\frac{3}{4}$ gal., pressure would be 19.5 ab.,—4.8 g.; to $\frac{2}{3}$, 22.2 ab.,—7.5 g.; to $\frac{1}{5}$, 73.5 ab.,—58.8 g., and so on, according to the rule given. These pressures would appear in reverse order, down to 14.7 lb. ab.,—0-lb. g. at the original volume, one gallon. If the cylinder then be stretched to 2 gals. capacity, the absolute pressure would be reduced to 7.5 lb. per sq. in.

The above is just what takes place when the volume of air is reduced by pumping water into a tank,—the rigid cylinder takes the place of the flexible one imagined above and the filling of water is equivalent to flexibility or telescoping, as a means of changing the volume of the air space.

Following are brief descriptions of a number of conventional air pressure outfits, with like environment, illustrating some of the many ways in which air pressure may be utilized to supply plumbing fixtures in buildings out of range of city pressure.

The pumps shown are hand-power, but, for any considerable service, gasoline engines or other forms of power may be employed. Power operation should have some automatic means of stopping or regulating the pump. Pump regulators operated by either the water or air pressure may be applied. Diaphragms with lever and weight, or even so simple a contrivance as a relief valve arranged to discharge into a counter-weighted falling receptacle so as to use the added weight of water to pull a switch may answer, all according to the form of power and whether it is desired to maintain a certain pressure, or, simply to stop an engine or motor.

The outfit of Fig. 62 is equivalent to that of Fig. 60 in point of service, but, instead of taking up room in the basement the tank is set in earth below frost depth with the countersunk head projecting through the wall into the basement. The water gauge is always placed at the end shown because the countersink or recess is a protection to the glass, and shortens the length over all. The lower gauge cock should have a drain (not shown) to empty and cleanse through. The glass is usually protected by guards. With the tank in the position shown, the sweating

surface is too small to cause annoyance; the support is everlasting; the water remains cooler in summer; no extra frost risk is incurred, and all essential parts are accessible. The tank may be placed entirely outside of the house wall and the gauge and connections piped into view. When projecting into earth or altogether buried, plain tanks should be proved tight, on the ground, at a higher pressure than the service will exert, and then thoroughly asphalted.

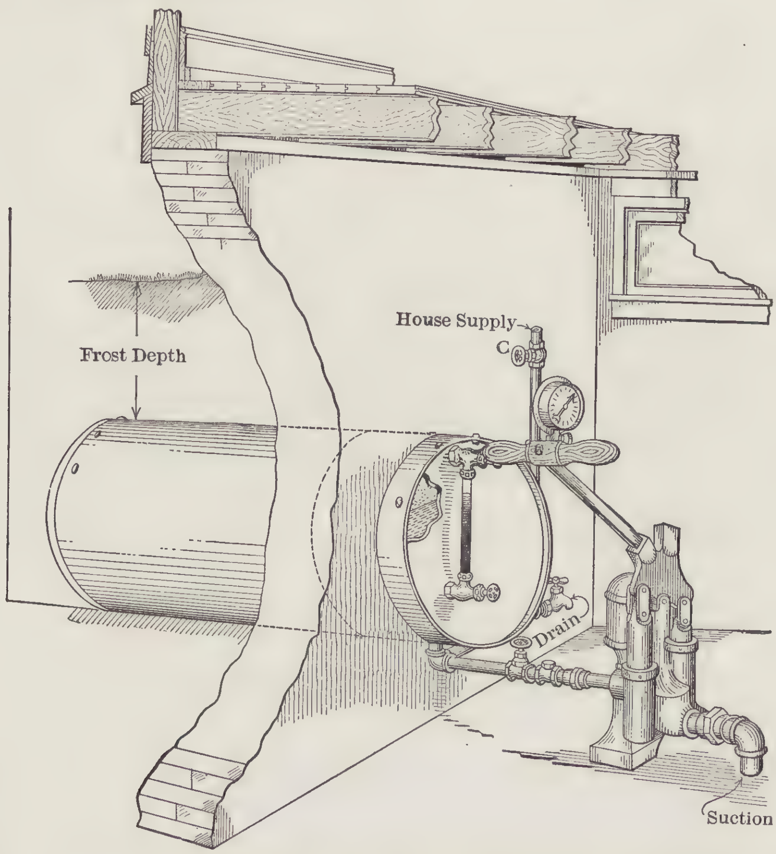


Fig. 62. Pressure and Storage Tank, Buried—Gauges and Connections Exposed to View in Basement

Fig. 63 is an end view of a double tank job. Two or more tanks may be connected for a singular service if the volume of water needed requires it. Each tank in a battery should be valved to cut out, or use alone, as necessary. In the job shown, one tank (**B**) is normally held in reserve, at high pressure, as a means of fire protection. Pipe **F** leads to reels of 1-in. hose in the rear hallways. Valve **D** being closed, the domestic service is confined to the low-pressure tank **A**, because the check **K** of high pressure tank **B** prevents the pressure from equalizing. Otherwise,

checks **K** and valves **H** serve the same purpose as stated for Fig. 60. **G** and **E** are drain openings; **F** and **C**, stop and waste valves; **D**, a gate valve, and **aa**, air cocks. Air may be pumped in at **aa**, if desired, but these cocks should never be opened without a pump connected, unless the tank is practically empty, because air is likely to be lost, as the volume, with any degree of water contents, must ordinarily be under more or less compression. No gauges are shown, but they are almost an essential feature of a double tank job. Air pressure raised above simple compression at any low stage of water increases rapidly by reducing its volume. The pressures that will thus be developed at higher water levels can be approximately deduced by adding the increment of gauge pressure, at the low level, to the corresponding absolute and figuring as before directed,—the air zone at low level being reckoned as 100 per cent.

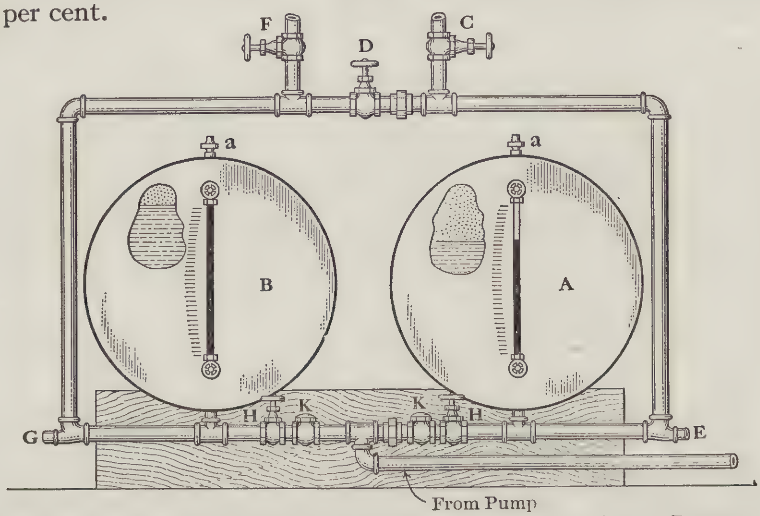


FIG. 63. DOUBLE TANK INSTALLATIONS CONNECTED TO HOLD ONE IN RESERVE FOR HIGH PRESSURE EMERGENCY SERVICE

Should there be urgent need for immediate supply of domestic water when tank **A** supply is low and there is not time to pump up tank **A**, opening valve **D** will substitute the reserve supply in **B** for the regular domestic service. If closets or other fixtures in the plumbing have low pressure trimmings that will not close tight under high pressure, it may be wise to also close valve **C** until the high pressure of **B** has transferred enough water to **A** to answer until pumping permits again restoring normal service. In some jobs, three tanks are used in order to utilize two kinds of water and still have a high pressure reserve tank for fire service.

The fire service and one low pressure tank, devoted to drinking water and closet supplies are hard water, as a rule; the other low pressure tank is generally for rain water, supplying baths, lavatories and culinary

fixtures, etc. A two tank job may answer for a dual supply, but it leaves all certainty of high pressure out of the reckoning, and thus becomes a poor dependence for the *double purpose.*

All connections from pump to two tanks may be the same for two kinds of water as those shown in Fig. 63. Two suctions must be brought to the pump, however. If small, a 3-way cock will answer to switch from one suction to the other. If the suctions are large, 2-in. or more, it will be better to put in two regular valves to control them.

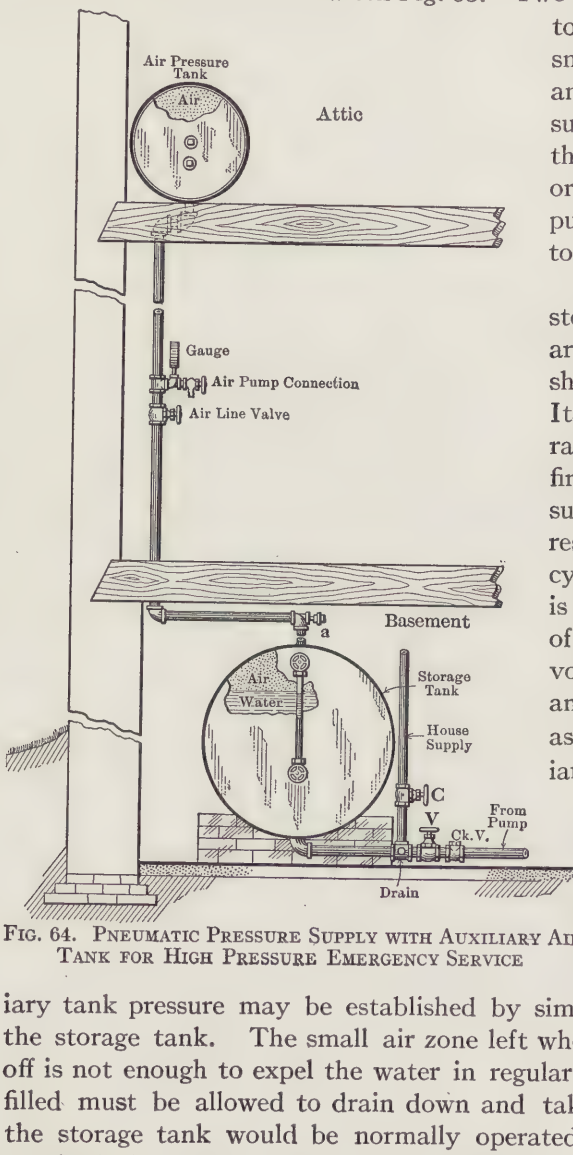


FIG. 64. PNEUMATIC PRESSURE SUPPLY WITH AUXILIARY AIR TANK FOR HIGH PRESSURE EMERGENCY SERVICE

Fig. 64 shows a single storage tank used ordinarily the same as those shown in Figs. 60 and 62. Its supply of water is arranged to be pressed into fire service, other high pressure needs, or, for lifting residual water for emergency domestic service. This is accomplished by means of an auxiliary air reservoir, kept at high pressure and situated in the attic, as illustrated. The auxiliary tank is $\frac{1}{3}$ the cubic capacity of the water storage tank, and is generally kept under 100 lbs. air pressure, with the air line valve closed. Some 50 lbs. of the auxiliary tank pressure may be established by simply pumping water into the storage tank. The small air zone left when the attic tank is shut off is not enough to expel the water in regular service and the tank so filled must be allowed to drain down and take air at **a**. Thereafter, the storage tank would be normally operated as any other, and the required air pressure for the auxiliary finished with the air pump. It is less the work, and usually the plan followed, to fill the auxiliary from atmosphere with the air pump,—no use of the air line valve being

made until there is call for the air in the auxiliary tank. The gauge always betrays the air pressure available.

All joints on air work will be hydrogen-tight if they are screwed up warm in gas-fitter's cement. Hose connections for fighting incipient fires may be made to the main house service if it is large enough, but it is best to take a separate line from below the house service valve so that control of the domestic supply for repairs will not jeopardize the fire service.

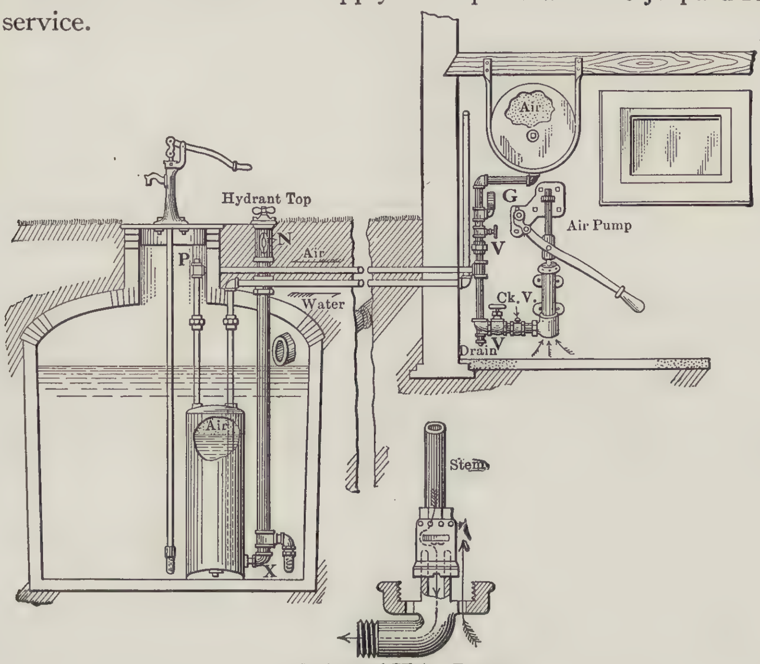


FIG. 65. SUBMERGED STORAGE TANK UTILIZING AIR PRESSURE TO LIFT DOMESTIC SUPPLY

Fig. 65 illustrates a little departure from the usual practice in pneumatic pressure service. The storage tank is a large size galvanized Kitchen "Boiler," 8 ft. long; 24 in. diameter; of 192 gals. capacity, with a side-hole near the bottom. It was lowered through the 30-in. cistern top and stands submerged on the cistern bottom a little to one side of the center. The air reservoir is a plain cylinder, 8 ft. long; 30 in. diameter; of 295 gals. capacity, and hung to basement ceiling by two $\frac{3}{8}$x$1\frac{1}{2}$-in. bar iron stirrups lagged to the joists, as shown. The whole contents of the storage tank are thus available and the service is therefore about the same between water fillings as is that of a 500 gal. tank used for both air and water storage, as shown in Figs. 60 and 62. It is more easy to operate,—the air is compressed direct by the air pump and the reservoir is large enough to expel two charges of water from the storage tank without recharging the air tank. The storage tank outlet

is through a tube extending to the bottom. The tank fills through a strainer, into an extended 1-in. hydrant valve above the pressure-washer,—the water passing down through and out of the valve into the tank by a course exactly the reverse to that taking place when a hydrant is used for its intended purpose. The hydrant valve is opened in the usual way when the tank is to be filled, the air line valve in the basement being first closed and the drain cock opened. When air ceases to issue from the drain cock, indicating the cistern tank to be full, it is then closed, the hydrant valve outside shut off and the air line valve in basement opened. The job, is then ready for service, provided the air pressure is sufficient.

A hydrant stem and body extended, with a strainer fitted in the body near the bottom was the most reliable home-made device the plumber could provide for filling the cistern tank. It is more positive than a check valve and can be examined or re-washered by removing the stem in the usual way. A detail sketch of the hydrant stem and valve, showing the course of the water toward the tank, and the holes bored by the plumber in the valve above the washer bridge, is given in connection with Fig. 65. If the waste holes in the bottom casting, indicated in the detail sketch, are large enough to let trash pass into the hydrant body they should be closed, to prevent trouble with the valve washer.

The nozzle hole (**N**) in the stock was wired closed with a piece of sheet lead. The pipes in the cistern are arranged so the tank can be removed through the cover well if necessary. The cistern being empty at the time, the job was first filled and tested by introducing water at plug **P** in the cistern mouth.

The examples of application shown in the sketches herewith together with the hints given in the text, though without minute detail or strained efforts at extreme accuracy, should be ample to suggest a much wider application of pneumatic service than many have heretofore practiced.

CHAPTER XXV

Outside Wood Tanks—Making and Erecting

Elevated outside tanks are most frequently of the circular wood-stave type because of the length of service of such, cheapness in many localities, ease of erection and repairs, their comparative immunity from frost damage and the fact that some leakage, at times, out of doors, is attended with slight consequences. Stave tanks are by no means confined to outside service. With a safe pan, such as is absolutely necessary for metal-wall inside tanks the circular wood tank is preferable to other types in some instances, and for one reason or another is doing service in many places. Cedar, cypress, chestnut and white pine woods are suitable. Cypress is the commercial ideal, especially for large tanks, though yellow pine and other woods are used. Cypress shrinks and swells less than other woods and will not give off any taste or odor or color. It is very straight grained and will warp and twist but little. Staves and bottom 3-in. thick are made for 35000 to 50000 gal. tanks; $2\frac{1}{2}$-in. for 20000 to 35000 gals.; 2 to $2\frac{1}{2}$-in. for 5000 to 20000 gals., and $1\frac{1}{2}$, $1\frac{3}{4}$ or 2-in. staves, with 2-in. bottom for 5000 gals. and less. These, governed somewhat by relative diameter and depth, are of sufficient strength, as may be noted in practice. The larger sizes do not require a stave heavier in proportion to relative contents, for the reason that the diameter to height is seldom less than as 3 is to 2, and sometimes as much as 4 to 1. This is partly by design to avoid hooping and stave strength, to counteract excessive lateral pressure, partly to keep within easy limits of suitable stave timber and partly on account of the dimensions necessary for stable foundations. Small sizes are of about equal height and diameter, exceeding in height, usually. If the height is unusual, the expense of safe hooping of staves of minimum thickness increases. It is best to make no tank bottom less than 2 in. thick, and, in general, strong bottoms are cheapest as the extra expense on grillage and dunnage (carrying the whole weight of tank and contents) for a light bottom is greater than the possible saving on light bottom pieces.

Tanks of any type can be had in the market, but instances of excessive freight, happy local facilities in the way of tools and cheap timber, or, a long-service guaranty where the contractor desires to have the initial quality of the best rather than make up deficiencies, possibly greater in cost, later, may determine one to see personally to the making as well as erection of a tank. The work is simple and a brief presentation of some of the points involved will enable a carpenter to get out the material either by hand or with planing mill help.

Staves are not ordinarily curved to the circumference of the tank, but have parallel inside and outside faces; the joint edges are tongueless planes converging to the center of the tank. The width of staves with chord faces is limited by the depth of chime-groove suitable for the thickness; by increasing need for curved hoop surface in very wide staves and, by the reduction of joint surface that would result from arcing the hoop side. The effect of width on the chime joint is illustrated by the groove-depth, inside face, and end-of-bottom lines, in Fig. 70, from which it will be noted that the wider the stave the deeper the groove must be to avoid butting and the less is the projection of bottom into groove at the joint. Too little hold at any point in the chime may cause very stubborn leakage

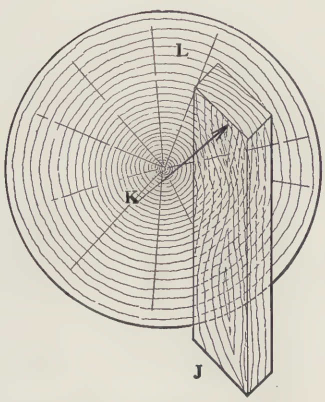


Fig. 68. Coefficients of Conduction

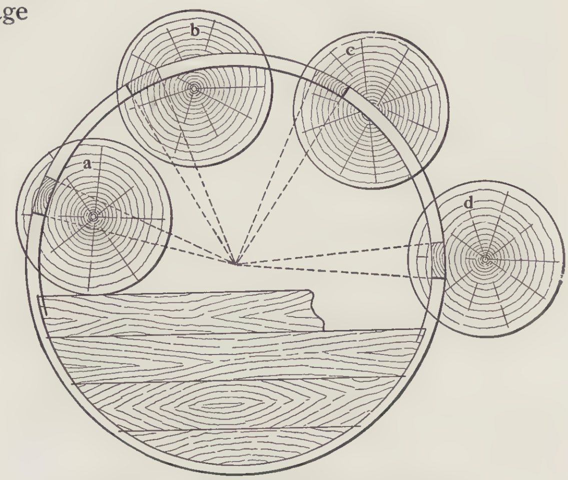


Fig. 69. Selection of Wood for Staves

that is not susceptible of swelling "shut." Six inches is considered the limit of width for staves of large tanks. Three to $3\frac{1}{2}$ in. does well for 3 to 6 ft. tanks; $3\frac{1}{2}$ to $4\frac{1}{2}$ or 5 in. for 6 to 12 ft. and uniform or random width, 6 in. or less for tanks over 12 ft. diameter.

There is more in the selection of timber than is usually believed. It has been determined that there are three coefficients of thermal conduction for woods according with directions **J**, **K**, **L**, Fig. 68. The calorific loss varies for different woods but the average for **J** compared with **K** is about as 30 is to 11; with **L**, as 30 to 10. Considering the slight difference in thermal radiation between **K** and **L**, the stiffness edgewise, and small water absorption by side surface of a timber cut from the log-position shown in Fig. 68 and at **a**, Fig. 69, it appears best to make staves of lumber that will bring the ligneous layers parallel with the hoops and the annular rings together as joint-surfaces (the position of nature), as would result if all the staves of a tank were from position **a**, Fig. 69. Sections **a**, **b**, **c**, and **d**, Fig. 69, afford a basis for studying the

relation of grain to stiffness; flexibility and stiffness edgewise and sidewise, the likelihood of splitting from nailing, etc.,—**b** showing the direction of annular rings in quarter sawed lumber. Fortunately the best kind of pieces for tank staves are those most likely to be found in stock, as they result from the ordinary and economical practice of "slabbing" the log and sawing the flitch straight through as is done for floor joists, fence, etc., without quartering or turning. No special sawing facilities are necessary and any country mill can therefore supply the staves in the rough. When practical, work the staves so that the lower end, as to growth will be at the bottom end as a stave. Endosmose action due to cellular structure of the wood favors the movement of sap in trees,—the same rather than mere capillary action in such lengths as those of staves, is probably true of its action with reference to water of absorption from the tank. And, doubtless, on account of the uniform fluidity of water, its tendency is always to travel from the stump end. If this point is observed it will be rare, with sound wood staves of equal quality,

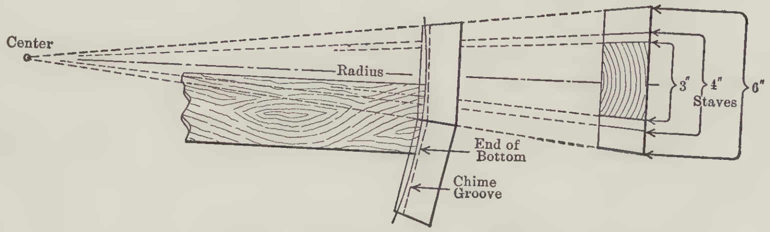


Fig. 70. Stave Templets

to observe some staves of a tank to be soggy looking (really soaked with water) while others next appear to be and are comparatively dry.

Stave lumber is not likely to be, as sawed, uniform in thickness, and though it need not be made so, it should be reduced to a common thickness at the chime, and the bottom groove should be cut to leave the same thickness to hoop face in each stave. Two to four inches of end below the bottom of groove should be allowed, according to thickness of bottom. The staves may be of varying width according as the lumber will work up, keeping in the neighborhood of widths for sizes already mentioned. It will be necessary (better at least) to make a templet block for each width of stave, if the beveling is to be done by hand. Heavy cardboard or a mere diagram may also answer for setting the bevel to try the joint faces which should be approximately true. To make a templet, the radius of tank (laid off on a plank) should cut the center of a block representing a section of the stave of a particular width. The width of stave should then be marked at outer circumference, perpendicular to and centered over the radius line. Then strike two radii cutting these extremes of stave-width. Then, with the

thickness of the stave set off at circumference perpendicular to and crossing these radii, a diagram of horizontal section of a stave for that width is complete. If a diagram is to be used for setting a planer or edger, all the widths may be similarly diagrammed over one thickness as indicated in Fig. 70.

Circular tanks must taper more or less, growing smaller from bottom to top, else the hoops could not be easily placed; would fall off or out of place in dry weather and could not be driven down to place, nor to check leakage. Some 3 in. or more taper (stave leaning centerward from the vertical) will answer. On an 8-ft. tank, 6 in. difference in diameter makes $18\frac{3}{4}$ in. difference in circumference or $\frac{1}{4}$ in. per stave, for 4-in. staves, —$\frac{1}{8}$-in. taper, on a side, from bottom to top. The stave may be scribed and the whole taper taken from one side,—the ends are thus thrown slightly out of horizontal when erected, but not enough to be worth considering.

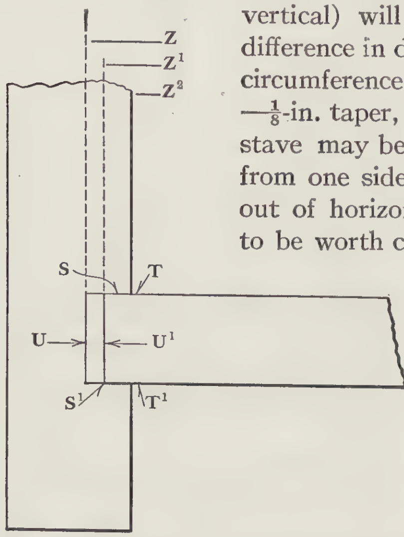


Fig. 71. Elements of Chime Joint

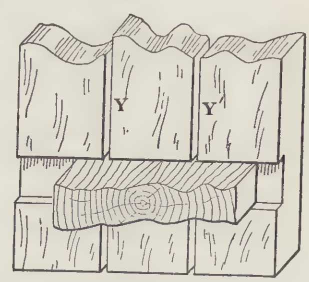


Fig. 72. "Chime Bound"

By noting the chime features of Figs. 70 and 71 together, the function of the chime-joint as a water-tight connection between staves and bottom will be seen. The staves resist lateral pressure; the bottom sustains the weight; the bottom pieces should be well dowelled together; the chime groove holds the staves in place and is the necessary factor of margin for variable tank circumference,—resulting from the inaccuracies of practical work and of weather changes before and after erection.

No general taper of the ends of bottom pieces from too thick for the stave groove down to the groove width should be made. Let the entering bottom edge and for some distance back be practically with parallel sides, with slight corner chamfering to enter by. If the bottom is to stand a few days before erection, leave it *full* thickness of groove width to avoid looseness from drying out; if a stave taps over too tight, a block plane can be used on the bottom as necessary, when erecting. Surfaces **S**, **S**^{1}, of the groove, and **T**, **T**^{1} of the bottom, Fig. 71, are all that can be depended upon to hold the water in at the chime; any at-

tempt to utilize surfaces **U** and **U**^{1} by butting will result in "chime-binding" the staves as shown at **Y**, **Y**^{1}, Fig. 72, thus subjecting the stave joints to leakage from a cause that is both difficult and expensive to remedy. Loose oakum can be used to advantage in the space **U** to **U**^{1}, not as a dependence for tightness but as a precaution. Loosely laid in the back of the groove, it is a good trap for sediment which helps to choke up a leak, and the swellage of the oakum aids in taking care of leakage that gets by **S** and **T**.

Supposing distance **U** to **U**^{1}, to be $\frac{1}{4}$-in. in an 8-ft. tank, the difference in circumference between **Z** and **Z**^{1} diameters would be $1\frac{6}{10}$ in. This is too small to divide, in any way, over uniform width or multiples of different widths of staves, with a view to prefiguring the stave circumference to make it come out right in erection,—the drying out factor alone prohibits such a calculation, for wood. It is therefore best to elect an outside circumference for hoop length purposes; allow $\frac{1}{8}$, $\frac{3}{16}$ or $\frac{1}{4}$-in. **Z** to **Z**^{1} space, according to size of tank; $\frac{3}{8}$, $\frac{1}{2}$ or $\frac{5}{8}$-in. **Z**^{1} to **Z**^{2}, according to thickness of stave, for groove depth; cut the bottom to agree with **Z**^{1} diameter; make *enough* staves, with the angle of joint faces proper for their width as before directed, and finish the stave circle when erecting, by altering the last stave needed to fill the gap. This leaves the chime space **U**, **U**^{1} to be preserved by close attention when tapping the staves to place on the bottom as they are erected. The chime space may be assured in several ways. When one stave has been set, the joining edge of the next one has only to be brought "flush," provided bottom edge and chime groove are regular, as they should be; the other edge is in view. A segment board with proper arc can be tacked to tank bottom with arc edge standing back the proper distance to which the inner face of staves can be tapped up to. A leather or other strap can be used to give the desired clearance. This, however, requires strips within, tacked to bottom with end against stave after stave is set and before strap is pulled out, to hold against braces footing on platform floor and against stave opposite chime groove, to hold stave in place,—unless nailing is resorted to. The inner strips or segment board have to be used because either nailing or bracing needs support from behind to keep the stave from tapping up tight. Where the chime groove is wide, sometimes a narrow strap or strip will answer to hold the stave off, but whether *thus* held off or by segment board, it is the usual and practical way to boldly nail through the center of width of the stave into as near the center of bottom thickness as the scheme for holding off will permit instead of using preliminary outside bracing. A single nail to the stave will do no harm and if pointed to one side of the tank center (head leaning toward the erected staves) it will resist any tendency of the stave to work or jar off by drifting it tighter against the erected stave next to it.

To erect the tank, assuming the platform ready and dunnage placed, hoops cut and draw bolt ends attached: Place the bottom across the dunnage, not forgetting provision for pipe attachment and drive them together over the dowel pins. See that it projects evenly and enough, beyond the ends of dunnage at all points. Paint the board edges with

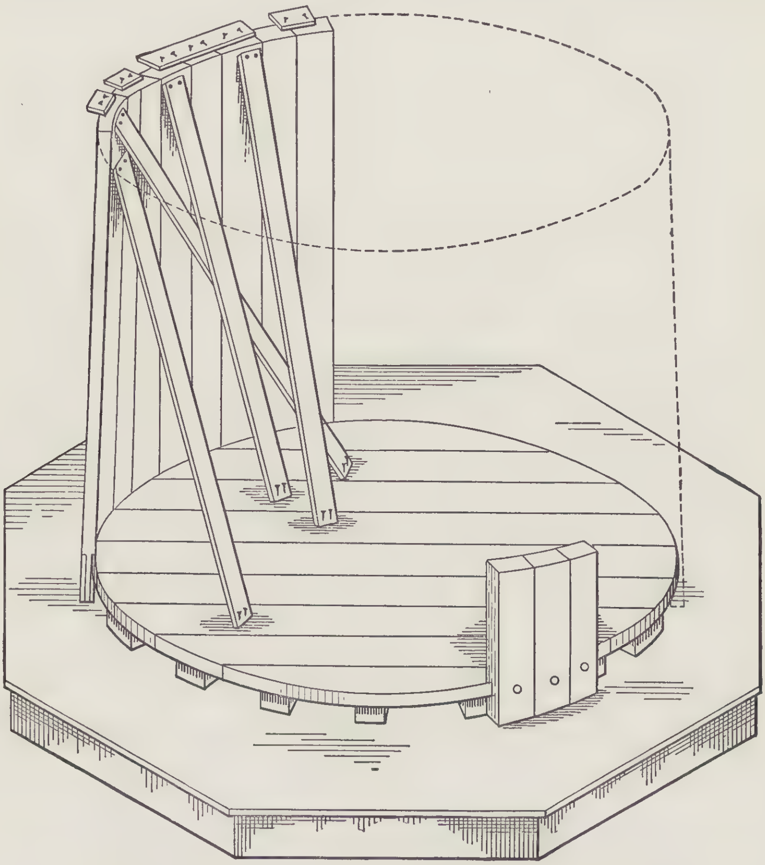


FIG. 73. ERECTING A CIRCULAR TAPERING WOOD STAVE TANK

thick white lead in oil (the same may be done with end edges and chime groove, later); anchor to the dunnage at pipe-hole or otherwise, and then begin by plumbing the first stave, tapped up, *out of plumb* with reference to converging to tank center equal to the taper on a side,—*plumb* as regards the center of width or either joint-edge being all in the same vertical plane. Two braces are needed to tack the first stave into position. Their positions are shown in Fig. 73, first stave at the left, the braces being strongly tacked to the stave near the top and spread to form, with the stave, a stiff tripod when tacked to the bottom boards as shown. No outer bracing is shown in the sketch (nor is the

segment board to tap up to) but, in addition to driving a nail through the stave as stated and as indicated in the stave ends in the foreground, it is usual and proper to also foot an outside brace against the first stave from platform to chime height, to keep it from pushing off. A second stave is then added, tacked to place at the bottom and held in line at the top by a block nailed across the joint. Proceed so, until the fourth stave is reached; plumb *it*, and fasten to position with a brace as shown in Fig. 73, and so on, mixing the staves, if of different widths, and plumbing and bracing (with *two* braces, if necessary) every third or fourth stave, in order to correct the contour, until the gap is reduced to approximately two staves. If by measuring, the gap is found to be slightly less than any two staves remaining, reduce the wide one until they equal the gap; if the gap is considerably less than two staves, it may be best to divide the reduction, by taking some off of each and the most off of the wide one.

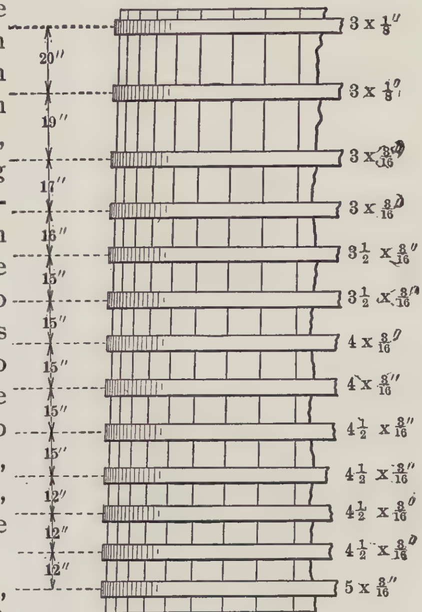


Fig. 74. Disposition of Hoops

The stave circle being completed, the hoop positions (bottom edge line) if not previously indicated should be marked at intervals around the tank, and the hoops drawn up moderately somewhat above the marks. Any stave noted to be projecting inward or outward at points should then be jarred into line and the bottom, top and middle hoops screwed up a little tighter and then tapped down to the line with the back of an axe, blunt wide claking tool or bar. The intervening portions of the staves should then be examined for irregularities, aligned as well as possible, and the other hoops tightened some, if expedient, and driven down to position. No undue strain should be brought to bear at this stage of the work. How tight to draw the hoops will depend upon how dry the staves are at the time,—swellage of staves when water is admitted to the tank may burst the hoops if they are pulled too tight to begin with. After swelling, if leakage is still apparent the draw-bolts can be tightened. It is necessary to anchor the tank, through pipe connections, or straps to floor timbers to keep it in place under wind pressure when empty.

Flat hoops are best in many respects. Round ones have too little

bearing surface for water tanks—wood compresses too easily—though silos are quite generally hooped with round rods which permit repainting both wood and hoop almost completely. The sizes and locations of hoops for a 50000 gal. tank as proven by long experience to be safe are given in Fig. 74. The distance and sizes for hoops for smaller tanks of the larger sizes may be proportional. The hoops catalogued by manufacturers of tanks ready to erect generally represent the minimum in number and strength of hoops for the different sizes catalogued and are a fair basis from which to infer necessary hoopage. Calculations for flat hoops based on the tensile strength of iron or mild steel need to carry a high factor of safety. Hoops are thin; their surface relatively large; they are exposed to the weather; one side cannot be reached to repaint; they are subjected to wide variation in strain and the water may be of a character to favor rapid corrosion through the moisture reaching the hoop through the stave.

The pressure tending to burst a tank at any point below the surface of the water is equal to 62.5 multiplied by the head (distance from point considered to top of tank) and then by the diameter of the tank. The product thus obtained divided by a factor of safety for the hoop material gives the cross-sectional area of metal for the hoop at the point considered. 10000 lbs. per inch is usual for steel, but as a hoop gives double the resistance of ordinary tension on a bar, the product referred to should be divided by 20000 for the area of section. The same result is obtained by multiplying 31.3 by the head and by the diameter and then dividing the quotient by 10000. The author proportions hoops in this manner, for all very large tanks, with the exception of those hoops that come above a line 4 ft. from the top of the tank,—the upper hoops are made the same or very nearly the same as the one that comes 4 ft. or more from the top. This is done because, while the water pressure in the tank calls for ridiculously light hoops near the top, deterioration, force of swellage from dampness, etc., must be taken care of regardless, and no disrupting pressure formula provides for such. For medium to small tanks, it is the author's practice to add to the pressure formula requirements a factor based on the compression surface in one joint-face of one stave. The thickness of stave in inches multiplied by the length in inches gives the compressive surface in inches. This is multiplied by 100 to 200, according to the dimensions of the tank, and the product divided by 10000. The inches of section thus found are divided by the number of hoops and the quotient added to the pressure formula requirement for each hoop. The hoop subject is well worthy of more room than it is possible to give it in a work of this kind and it behooves the builder of a tank to have the hoops amply strong for long service. Some disastrous wrecks of large tanks have occurred through light, or old corroded hoopage.

CHAPTER XXVI

Wind and Dead Load Stresses in Tank Structures

There are frequent occasions to erect supporting structures adapted for various service. Plumbers of all localities, but especially those of country towns, have their share of this work to contend with on wind mill and tank work, and are generally little prepared to solve structural problems of this kind, though they crop up often under conditions unfavorable to enlisting the aid of other men. In wind-mill work the structure usually serves to hold both the mill and the water tank. The added wind strain due to carrying the mill superimposed will be more than taken care of if the area of the wheel be added to that of the tank wind surface and the whole considered as being at the wheel height.

Mr. Paul T. Lesher has admirably treated some of the elements of this subject, his premises, in one instance, being peculiarly appropriate to discovering just the line of data needed by many who desire to figure such stresses for themselves. The method given may be used on both wood and steel structures. The following indicates the method given by Mr. Lesher for calculating the sizes of the various members of a tower:

"The water tank shown is 12-ft. in diameter, $10\frac{1}{2}$-ft. deep,—8800 gal. capacity—and the weight of the water 73400 lb. The tower is 34-ft. high and weighs about 8000 lb. The platform weighs about 7000 lb., and the tank about 2900 lb. Fig. 77 is an elevation of the tank and tower with an enlarged view of the railing support. Fig. 78 is a plan of the platform.

The first step is to consider the wind pressure, assuming the tank to be empty. The surface of a tank exposed to the wind at any one time is its diameter multiplied by its height,—in this case being $12\times10\frac{1}{2}$ $=126$ sq. ft.

For the wind pressure it is usual to assume 40 lb. per sq. ft. of flat vertical surface,—equal to about 90 miles velocity per hour, and to use only one-half of this value for pressure against circular sections. The wind pressure on the tank can therefore, be taken to be 20 lb., per sq. ft. The total pressure on the tank is thus 20 times 126, or 2520, the number of pounds pressure acting at a point midway between the top and bottom of the tank, or about 40 ft., above the base of the tower.

In determining the stresses in the tower by means of the stress diagram, it will be more convenient to consider this force as acting at the top of the tower,—8 ft., lower than the tank center. The amount

of the force acting at the top of the tower due to wind pressure on the tank can be found by simple proportion, as follows:

2520 lb.: **X** :: 32 ft.: 40 ft.

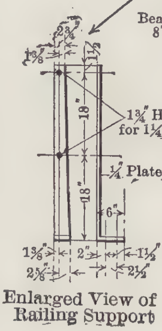
The new force, **X**, is thus seen to equal 3150 lb.

As there are 2 bents in the tower resisting this force and as it is required to find the stresses in one bent, the force acting at the top of one bent due to wind pressure on the tank will be one-half of 3150 lb. or 1575 lb.

For the wind pressure on the side of the tower 15 lb. per sq. ft. should be ample, considering that it is an open frame. This will give the panel loads as indicated in Fig. 79, the horizontal load at the top of the tower including both the pressure on the tank and the pressure on part of the tower.

The vertical forces for the stress diagram are now to be considered. The weight of the tank is 2900 lb., the platform 7000 lb., and the tower 8000 lb., giving a total of 17900 lb. As this pressure is supported by the four columns of the tower, the pressure on each column will be $\frac{1}{4}$ of 17900, or 4475 lb.,—taken as 4500 lb. for convenience in calculation and so indicated in the frame diagram Fig. 79.

Being now ready to draw the stress diagram, Fig. 80, lay off to a scale of $\frac{1}{2}$-in. equals 5000 lb., the horizontal wind force **ed**, **dc**, **cb** and **ba** on the load line **ea**, and the vertical dead load force **ai** and **ih**, as shown in the diagram Fig. 80.



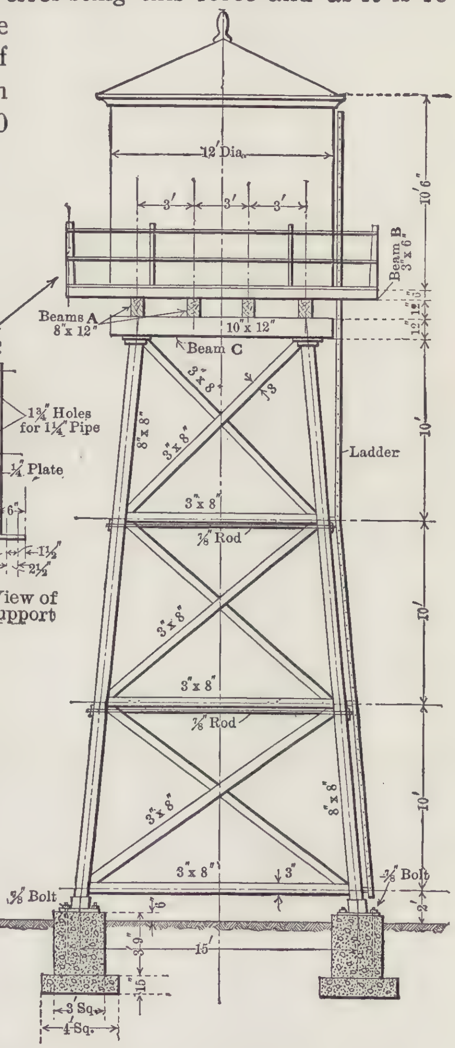


Fig. 77. Elevation of Tank and Tower,—Scale $^1/_{10}$-In. to the Foot

Consider first the forces acting at joint 1 in Fig. 79. The force **ih** is laid off to scale in the stress diagram, then start at **h** and draw a line

parallel to the line **HJ** in the frame diagram, Fig. 79. Next from **i** of the stress diagram draw a line parallel to **JI** of the frame diagram and where this line intersects with that drawn from **h** place the letter **j**.

The stresses around this joint have now been determined,—going from **i** to **h**, then from **h** to **j** and from **j** to **i** which is the starting and finishing point. In going from **i** to **h** the direction traveled was toward

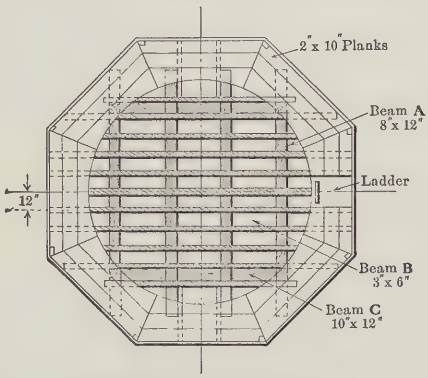


Fig. 78. Plan of Platform,—Scale $^1/_{10}$-In. to the Foot

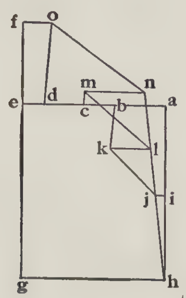


Fig. 80. Stress Diagram when Tank is Empty. Scale,—½I-n. Equals 5000 Lbs.

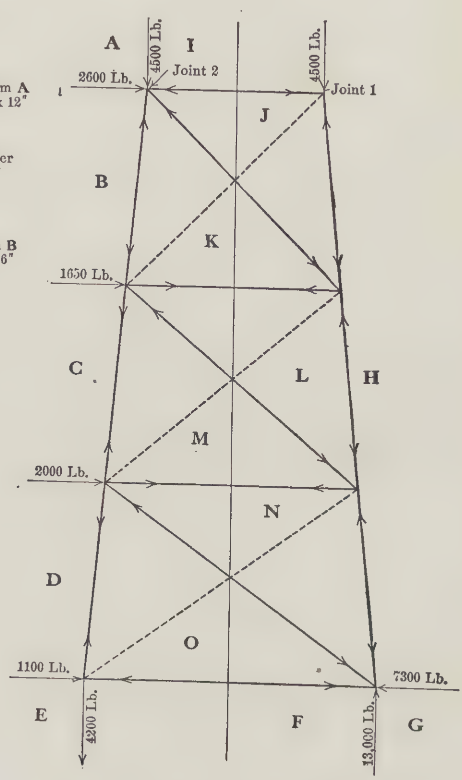


Fig. 79. Frame Diagram—Scale, $^1/_{10}$-In. to the Foot

the joint; from **h** to **j** the direction was toward the joint, so we place an arrow head pointing toward the joint and close to it on the line **JH** in the frame diagram, Fig. 79. From **j** to **i** the direction traveled was toward the joint, so we placed an arrow head pointing toward the joint and close to it on the line **IJ** in the frame diagram Fig. 79. By means of these arrow heads one is enabled to tell whether the member is in compression or tension. When the arrow heads on a line point toward each other the member is in tension, and when away from each other it is in compression.

Considering joint 2: The forces acting at it have already been

drawn in the stress diagram and are represented by the lines **ab** and **ai.** In going around this joint we start at **b**, going to **a**, and then to **i**, from whence we pass to **j**, and then from **j** draw a line toward the joint parallel to the line **JK** of the frame diagram, Fig. 79. From **b** draw a line parallel to the line **BK** until it intersects the line drawn from **j**. At this intersection place the letter **k**. Place the arrows in the frame diagram, Fig. 79, around this joint as explained in connection with joint 1.

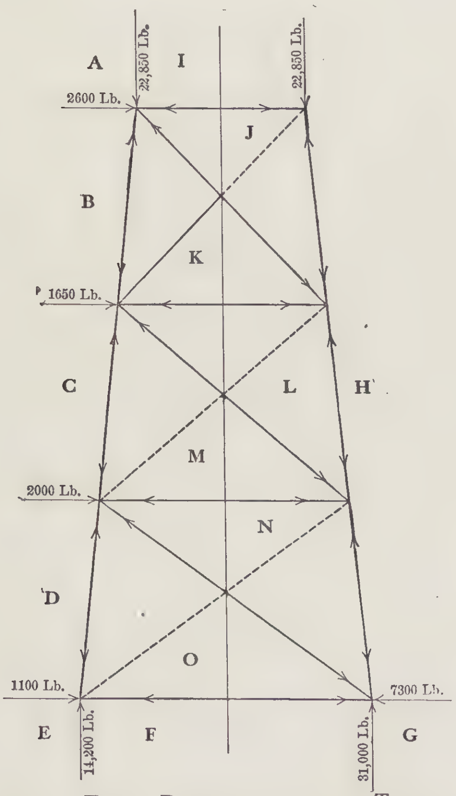


FIG. 81. FRAME DIAGRAM WHEN THE TANK IS FULL OF WATER,—SCALE $^1/_{10}$-IN. TO THE FOOT

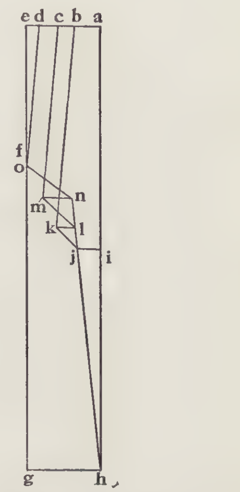


FIG. 82. STRESS DIAGRAM WHEN TANK IS FILLED—SCALE, ½-IN. EQUALS 10000 LBS.

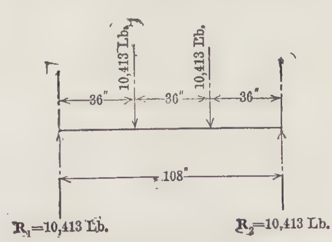


FIG. 83. THE LOADING ON BEAM "C"

The stresses at the other joints are found in like manner and when the stress diagram is completed we can scale the stresses in the different members. Table XXI gives the stresses in the structure under consideration.

Also draw frame and stress diagrams, Figs. 81 and 82, regarding the tank as filled with water and using the same wind pressure as before. In this case the column load will equal $\frac{1}{4}$ the weight of the water, plus 4500 lb. which was used in the first case. The weight of the water is

73400 lb., and $\frac{1}{4}$ of this is 18350 lb.; 18350 plus 4500 = 22850, which is the load on one column.

The stress diagram is then drawn as in the first case. The stresses found in both these diagrams are given in Table XXI.

Table XXI. Tower Stresses, in which — Denotes Tension, and + Denotes Compression

Symbols of Members	Stress with Tank Empty	Stress with Tank Full	Maximum Stress
BK	+2300 lb.	+20500 lb.	+20500 lb.
CM	— 700 lb.	+17500 lb.	+17500 lb.
DO	—4200 lb.	+14500 lb.	+14500 lb.
JH	+4600 lb.	+23000 lb.	+23000 lb.
LH	+4800 lb.	+25000 lb.	+25000 lb.
NH	+9800 lb.	+28000 lb.	+28000 lb.
IJ	+ 500 lb.	+ 2500 lb.	+ 2500 lb.
KL	—2000 lb.	— 1700 lb.	— 2000 lb.
MN	—3000 lb.	— 3000 lb.	— 3000 lb.
OF	+1500 lb.	+ 100 lb.	+ 1500 lb.
JK	+3300 lb.	+ 3300 lb.	+ 3300 lb.
LM	+4500 lb.	+ 4500 lb.	+ 4500 lb.
NO	+6000 lb.	+ 6000 lb.	+ 6000 lb.

The wood in the tower and platform is taken to be long-leaf yellow pine. In the table of stresses it is found that the maximum compression in the columns is equal to 28000 lb., which occurs in member **NH**. We will consider this member as a column 120 in., in length, supporting a load of 28000 lb., and will use the following formula for the column:

$$\mathbf{Sc} = \mathbf{U} - \left(\frac{\mathbf{U} \times \mathbf{l}}{100 \times \mathbf{d}}\right) \text{ in which}$$

Sc = the ultimate breaking value of the column per square inch of cross section.

U = the ultimate compressive value of the column per square inch of cross section.

l = the length of the column in inches.

d = the least unsupported or unbraced side of the column in inches.

U = 4000 lb., for yellow pine. Assumed to be 8-in.

The formula with figures substituted is then

$$\mathbf{Sc} = 4000 - \left(\frac{4000 \times 120}{100 \times 8}\right) = (4000 - 600) = 3400 \text{ lb.}$$

Using a factor of safety of 4, the safe load per square inch will be one-quarter of 3400 lb., or 850 lb.; then 28000 lb., divided by 850 equals 33 sq. in., required in cross section of column. 33 in., divided by 8 in., equals $4\frac{1}{8}$, the number of inches required in the other side of the column.

As allowance must be made for bolt holes, notching, and defects in the timber, it is best to use a heavier timber, say 8×8 in., for the columns.

In considering the diagonal bracing it is found that member **NO** carries a compressive stress of 6000 lb. Although all the braces do not require it, designing all the diagonal bracing to take this stress, will make a more uniform looking tower as the diagonal bracing will thus all be the same size. Consider member **NO** as a column 192 in., in length, with the least side equal to 3-in.

The column formula will then be:

$$\mathbf{Sc}=4000-\left(\frac{4000\times192}{100\times3}\right)=(4000-2560)=1440 \text{ lb.}$$

Using a factor of safety of 4, the safe load per square inch will be $\frac{1}{4}$ of 1440 lb., or 360 lb.; then 6000 lb., divided by 360 lb. equals 16.7, the number of square inches required in the cross section of the column. 16.7 sq. in. divided by 3-in. equals 5.6 in., the length of the other side,—3×8-in. timbers will be safe under any circumstances and more in keeping with the post, than 5.6×3.

Members **KL** and **MN** are in tension, **MN** carrying the largest tensile stress, which is 3000 lb. A $\frac{7}{8}$-in. rod will carry this stress with safety, so rods $\frac{7}{8}$-in. diameter may be used for members **KL** and **MN**. At members **KL**, **MN** and **OF** also use 3×8-in. timbers, as in addition to the rod, a bearing for some of the thrust caused by the ends of the diagonal bracing must be provided.

In Fig. 79 it is found that **EF** represents a force of 4200 lb., which is the force required to hold the column down to the base, when the wind blows while the tank is empty. The post foundation must therefore, weigh not less than 4200 lb., as it is the foundation that counterbalances the overturning moment. This lifting force is resisted by the foundation bolt,—a $\frac{7}{8}$-in. bolt answers the purpose.

In Fig. 81, **FG** represents a force of 31000 lb., which is the maximum pressure the foundation will exert upon the supporting soil, when the tank is filled and the wind exerting its pressure. Assuming the supporting soil capable of bearing 2500 lb. per sq. ft., the area in square feet of the foundation base will be $31.00\div2500=12.4$ sq. ft.

The construction of the platform is shown in Fig. 78. The tank rests directly upon the supporting beams **B**, which are 11 in number. The tank, when filled with water weighs 76300 lb., therefore, the maximum load on 1 beam will be $\frac{1}{11}$ of 76300 lb., or 6936 lb. The maximum span of the joists is 36 in. For a beam uniformly loaded, the maximum bending moment equals $\frac{wl}{8}$ in which **w** equals the load in pounds and l equals the span in inches.

The bending moment will then be $\frac{6936\text{x}36}{8}=31212$ inch-lbs., and this divided by 2000 lb. (the safe fibre stress per square inch for long-leaf yellow pine) equals 15.6 which is the section modulus required.

The section modulus of a rectangle equals $\frac{bd^2}{6}$, in which **b** equals the breadth in inches and **d** the depth in inches. Assuming a depth of 6 in. for the beam $\frac{b\text{x}36}{6}=15.6$, and **b** equals 2.6 in. The next size larger piece-stuff stock is 3×6-in., the size timbers to use for beams **B**.

Beams **B** in turn rest upon beams **A**. Again using the load of 76300 lb., and adding to it the weight of the platform, 7000 lb., the total load resting on the four beams **A** is seen to be 83300 lb. The load on one beam will accordingly be 20825 lb.

Beams **A** have a span of 108-in. The bending moment will therefore, be $\frac{wl}{8}$ or, $\frac{2825\text{x}108}{8}=281138$ in.-lbs.

Section modulus $=\frac{281138}{2000}=140.6$.

Assuming a depth of 12 in., then $\frac{b\text{x}144}{6}=140.6$ and $b=5.9$ in. Use 8×12-in. timbers for beams **A**.

Two beams **A** exert pressure upon beams **C** and as the end reactions of each beam **A** equals $\frac{2825}{2}=10413$ lb., the loading on beam **C** will be represented by Fig. 83. The maximum bending moment in this case equals 36 in.$\times$10413 lb., or 374868 in.-lbs.

Section modulus $=\frac{374868}{2000}=187.4$.

Assuming a depth of 12 in. Then $\frac{b\text{x}144}{6}=187.4$ and **b** equals 7.8-in.

Beam **C** is also required to take a compressive stress of 2500 lb., caused by the wind pressure; therefore, use 10×12-in. timbers for beams **C**.

CHAPTER XXVII

Large Wood Tank and Support

The design shown by Figs. 85 to 89 is for a large wood tank and wood supporting structure suitable for heavy factory storage purposes, farm irrigation, village or railroad service. In the description of another design strain diagrams will be found for the various members of the structure, sufficient to enable one to determine, for any size tank, the size and strength necessary for wind strain and load for supporting members and braces, both as to compressive and tensile strains.

In Fig. 85 is the plan of foundation piers, vertical posts, ground sills and diagonal braces in the position they will occupy, together with

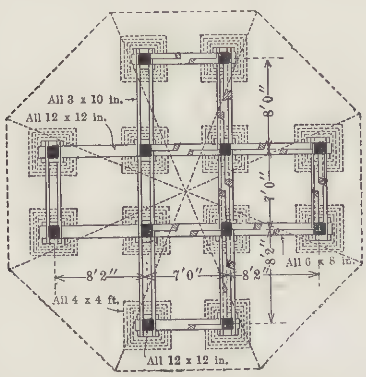


FIG. 85. PLAN SHOWING SILLS, PIERS, POSTS, ETC.

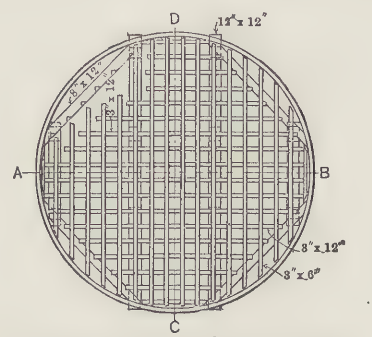


FIG. 86. PLAN OF GRILLAGE SUPPORTING THE TANK BOTTOM

various sizes and dimensions. The diagonal dotted lines represent the hips of the roofs as they should be placed with reference to the frame supporting the tank.

It makes little difference as to whether an outside tank structure of low height settles slightly if the sinking is uniform, though by figuring a little, it will be seen that in this case the piers are loaded to something like 2800 lb. per sq. ft. of footing. There being twelve 4x4-ft. pier footings—192 sq. ft.—and approximately 500000 lb. to be supported. Of this weight, about 80000 lb., are piers; 50000 lb., tank structure; 16000 lb., tank cover, and the balance, some 400000 lb., water.

Fig. 86 shows the tank bottom supports which consist of 12x12-in. top plates, 3x12-in. grillage, 8x12-in. mortised girders, and 3x6-in. dunnage all in plan position, with sizes indicated. The girders are mortised 8-in. deep to receive the tenoned ends of the grillage and are also notched down over the top plates. The grillage is notched over the top plates

so as to make them even or flush with the tops of the girders, and the dunnage is notched over the grillage, as indicated.

Fig. 87 represents a plan of the roof with a portion broken away to show its framing and supporting timbers.

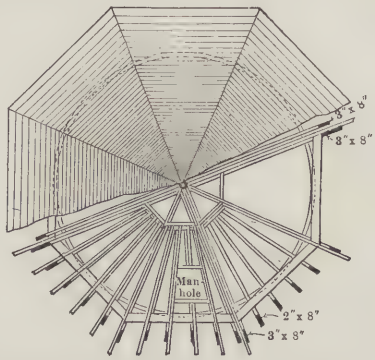


FIG. 87. PLAN OF ROOF, SHOWING PART OF ITS FRAMING

Fig. 88 is a general elevation of the tank and structure, seen from position **C**, line **C-D**, Fig. 86. The discharge pipe is shown as it would appear when provided for wagon or train service. The long diagonal braces are omitted and two pairs of X-braces with cross-ties to posts take their places as pipe supports where the long braces would interfere with the course of the pipe. The supporting structure as shown is 20 ft. high; when lower, the discharge pipe can be brought out through the grillage space if water is to be drawn for a wagon or other carrier at the tank.

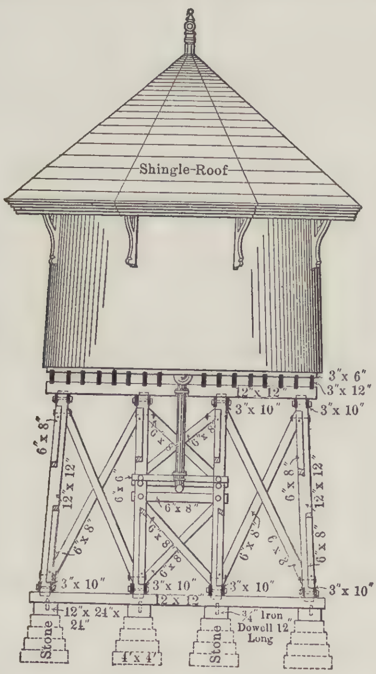


FIG. 88. ELEVATION OF TANK AND SUPPORTING FRAME WORK LOOKING FROM POSITION C OF LINE C-D, FIG. 86

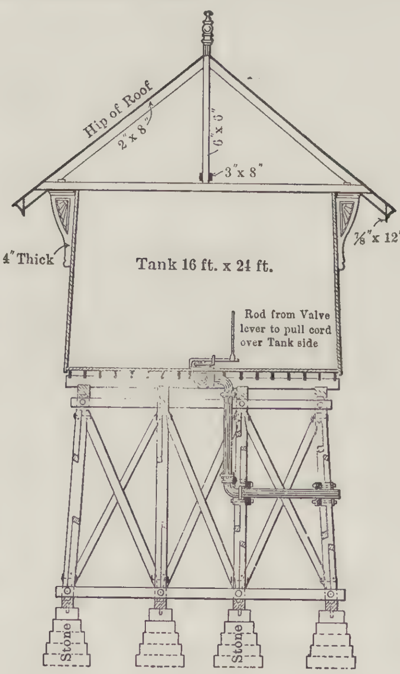


FIG. 89. SECTION OF SUPPORTING FRAME AND TANK, LOOKING FROM POSITION A OF LINE A-B, FIG. 86

In Fig. 89 is shown a vertical sectional elevation through the tank and roof over an elevation of the supporting frame work, looking from

position **A**, line **A-B**, Fig. 86—just quartering from the view shown in Fig. 88. The rod from the valve lever attaches to a sash cord or chain threaded through pulleys in the roof space and down outside,—usually beside the ladder rails to a ring within reach of the wagon-man.

Large plain outlet valves close violently when used under a strong head of water. For this reason, none but such as have a dash-pot or cushion of some type should be employed in deep tank service.

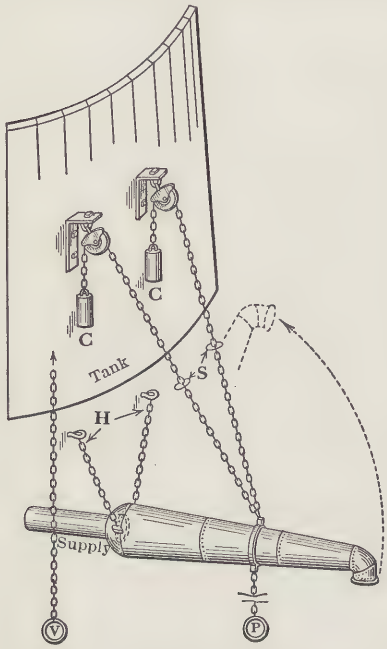


FIG. 90. DELIVERING SPOUT AND HARNESS FOR WAGON OR R. R. SERVICE

A hose or counterbalanced drop pipe is used on the discharge for wagon or locomotive service.

A tilting spout and its suspension harness are shown in Fig. 90. The hinge chains, **H**, attach to ears on the supply end of the spout and fasten to eye-bolts in the timbers, ladder legs, or other convenient parts. The counter-weight brackets fasten to the ladder, its bracing, or to the staves. **S** indicates stops on the tilting chains, —stop brackets for the weights **CC**, may be provided instead, if desired, and the weights could be adjusted to act as lowering stops by butting the housing of the pulleys. **P** is the ring by which to pull the spout down. **V** is the valve pull,—the valve chain can be arranged so that pulling the spout down will tilt the valve open at the proper time.

For wagon use a short piece of hose is often used on the end of the spout, as it is sometimes difficult to bring the opening of a wagon tank to a precise spot. A lug not shown is riveted on to the top of the supply pipe, to prevent the spout from slipping too far back as it tilts.

An overflow pipe large enough to take care of the utmost incoming supply should be placed on all tanks. The current, friction from dropping and warmth of the incoming water, prevent any serious trouble with ice in large tanks unless the climate is very severe. The staves and bottom of this tank are 3 in. thick, and no stave more than 6 in. wide.

The following bill of lumber is needed for the tank structure and cover shown in Fig. 88. 12x12-in. stuff:—2 sills, 26 ft. long; 2 sills, 10 ft. long; 12 posts, 18 ft. long; 2 caps, 24 ft. long; 2 caps, 10 ft. long; 4 girders, 8x12-in., 13 ft. long. Ties, 3x10-in.:—four 26 ft. long; four

24 ft. long; and eight, 10 ft. long. Joists or grillage, 3x12-in.:—six, 24 ft. long; two, 22 ft. long; two, 18 ft. long; two, 16 ft. long; two, 14 ft. long; two, 11 ft. long, and two, 8 ft. long. Dunnage, 3x6-in.:—six, 24 ft. long; two 22 ft. long; two, 21 ft. long; two, 19 ft. long; two 17 ft. long; two, 13 ft. long, and two, 7 ft. long. Braces, 6x8-in.:—twenty-eight, 18 ft. long; four, 10 ft. long, and four, 9 ft. long. Same for pipe support:—two, 6x8-in. 9 ft. long, and three 6x6-in. 9 ft. long. Roof post:—one, 6x6-in., 14 ft. long. Roof ties:—four, 3x8-in., 30 ft. long; four, 2x8-in., 15 ft. long, and thirty-five, 2x8-in., 12 ft. long. Eight 2x6-in. heel boards, 11 ft. long; eight, 2x8-in. hip-rafters, 22 ft. long; thirty-two 2x8-in. common rafters, 18 ft. long. 1300 board feet, sheathing; 600 ft. ceiling; 140 ft. $\frac{7}{8}$x12-in. facia boards. 140 linear feet each of $1\frac{1}{2}$x$1\frac{1}{2}$-cove molding and $1\frac{1}{2}$x8-in. crown molding.

Aside from the tank masonry and above bill of framing lumber, the water-pipe equipment, 8 brackets, and one finial are needed; also 100 $\frac{3}{4}$x20-in. bolts, twelve $\frac{3}{4}$x12-in. iron dowel pins, for the piers; 225 $\frac{3}{4}$x3-in. cast washers and one keg of 40d spikes, besides small nails, hinges for the trap door, etc.

Tanks built as shown are safe, such having been used for many years without a mishap.

CHAPTER XXVIII

Wood Storage Tank, with Piping, on Steel Tower

Some of the poor features of many common tank jobs are: light weight metal that soon pits through and is easily strained at seams from the action of sheet ice; lack of anchorage to hold them down against high wind when not full; absence of balcony and rail; outside delivery pipe; ladder so close to tank wall as not to leave a foot hold, etc.

A good wood tank well sheltered will serve 40 to 50 years; when merely covered, it should stand at least 20 years. A good 8x8-ft. tank of 2-in. cypress is shown in Fig. 95. The salient features of the outfit are: a 4-post 3x3-in. galvanized steel angle tower braced out with 2-in. and X-laced with $1\frac{1}{2}$-in. galvanized angles and galvanized bolts, all surmounted by steel eye beams to receive the wood work; wood grillage (joists) and dunnage (false bottom or supports for tank bottom to rest on); wood balcony floor, covered with galvanized iron; pipe standards and guard rails; wood beam canopy framing, galvanized roof, copper finial, and a frost proof pipe box arranged so that lines of pipe can be repaired or renewed without opening the box. Assembled as shown the tank has sufficient shelter and is accessible from any quarter; any hoop can be tightened, driven down or renewed; any stave calked or renewed; a new bottom board put in; a new line of pipe placed, removed or repaired, without the aid of scaffold, derrick or guy pole and without disturbing the balcony, railing, standards or canopy.

The sketches shown are fairly well proportioned. A general elevation with the tank and sub-structure is represented in Fig. 95. Below the tank elevation is an elevation of the platform and in the upper right hand corner a plan view of it,—these are all broken to show construction and **X** indicates corresponding corners.

The wood work begins on the eye-beams with two 8x10-in.x14-ft. timbers gained down $\frac{1}{2}$-in. over the eye-beams and stirruped to them with 1-in. rod stirrups passed down through auger holes bored so the stirrups will straddle the eye-beams obliquely. The ends of the stirrups pass through a straight bar of $2\frac{1}{2}$x1-in. iron under the eye-beams and there is a flat iron sunk in the beam at the top for the stirrups to pull down on to prevent slipping or rocking of the beams. Over these timbers is placed a grillage of 2x12-in. joists notched down over the timbers $2\frac{1}{2}$-in. and gained into them $\frac{1}{2}$-in., the grillage being cut to an octagon form. Between the grillage pieces, blocks of 2x8-in. joists were filled in over the timbers to act as bridging. Across the grillage and somewhat less in length at each point than the inside diameter of the tank

at the bottom, is placed dunnage pieces of 4x6 timber, upon which the tank bottom is assembled.

A $\frac{7}{8}$-in. common tongue and grooved yellow pine floor is layed over the balcony space to form a walk-way around the tank, the floor projecting 2 in. over the skirting which is $1\frac{1}{2}$x12-in. plank. The walk-way floor is covered with galvanized iron bent down 2 in. at the outer edge and turned up midway between the ends of the dunnage and the inner edge of the tank staves. A sheet metal ferrule is extended from the top edge of the floor sheet under the tank to below the bottom of the platform floor. Any leakage that may drop outside the ferrule line thus finds its way off the platform at the outer edge and what falls inside the ferrule ultimately drops to the ground because the grillage and dunnage are both open under the tank, except where the frost-proof box is extended up to the tank bottom. The pipe box is covered over with sheet metal so as to convey leakage from over it. In general, all this is indicated in the plan and elevation, each of which is broken in a way to show progressive stages of construction from the beginning at the eye-beams to the finished job.

The canopy is held up by eight 2-in. pipe standards flattened 12 in. at the top and bent to the angle of the cover. These are lag-screwed to the under side of the rafters, and attached to the platform by means of 2x6-in. floor flanges, the holes coming over the floor inside the skirting being filled with wood screws and those over the floor outside the skirting between it and the water shed of the galvanized sheet being bolted.

The railing is formed by two lines of 1-in. pipe attached to the 2-in. standards as shown. The railing is all threaded right-handed except at the finish, where two male and female 45-deg. malleable bends are used and a right and left coupling used to join the two ends, as shown in the detail sketch beside the plan view, in which the 2-in. standard and flange with 1-in. 45-deg. bend attached by $\frac{1}{2}$-in. bolt and the right and left connections are shown.

The canopy frame consists of eight 3x4-in. rafters joined as shown in plan detail, **A**. In place of a spider casting a 4x12-in. undrilled pipe flange was bored to suit and bolted to the rafters, housed in, underneath, as shown in detail plan and elevation **A** and **B**. The canopy is surmounted by a 6-in. copper tank ball,—a galvanized bolt having been placed through the entering half and soldered inside before the ball was put together. This, with a deck flange slipped over the bolt and soldered to the ball in the neck makes an excellent finish to the crown of the roof. The opening in the pipe-flange "spider" affords an easy means of screwing up a nut and washer at the bottom to hold the finial in place. When it is intended to place or withdraw pipe from the frost-proof box by working from within the tank, rafter shoes or a hollow center

casting should be used where the rafters join at the top. Also the opening can be provided by using a flange with a nipple screwed into it and framing the rafter ends to the nipple. In this case the washer on the finial bolt must be larger than the hole in the flange.

Ordinarily on this size tank, no framing would be placed in the canopy except the skirting strips shown. For larger tanks, and for this size or smaller, if desired, an angle brace may be placed from each rafter to its standard, at an angle of 45 deg. To act somewhat as stiffeners and to keep wind pressure from tipping the tank when it is empty a rafter keeper brace made as shown in detail elevations **C** and **D**, is placed at each rafter; the uprights are well nailed together at the lower end, but are not fastened to the tank.

The delivery pipe is brought up through the frost-proof box and extended to above the overflow level as suggested at No. 3 in detail sketch **F**. The discharge for general domestic service, No. 4, is provided with a strainer. The laundry supply, No. 1, is stopped 2 ft. above the bottom and the carriage house and lawn service, No. 2, 4 ft. above the tank bottom.

Any considerable job is likely to call for a number of pipes to lead from the tank. Each of a number should be extended to a different level in the tank to accord with its relative importance. Fire service and the main domestic supply are stopped near the bottom; lawn sprinklers, carriage house and sewing machine motor supplies stop above the other lines so as to automatically save water for more important uses. If the pipes entering the tank are of liberal size or exceed 3 or 4 in number, a gang plate on the order of that shown in sketch **E** is essential. The plate is merely a flat slab of cast iron with bosses on one side drilled and tapped for the pipes. The tank bottom is cut out for the pipes and the plate bolted down to the bottom over a gasket through holes around and near the edge of the plate. When so fitted the pipes leading from the tank are accessible only by opening the frost-proof box.

In the arrangement shown the pipes were entered in a way to make them reachable through the tank connection without disturbing the box. An 8-in. cap was bored for the necessary pipes to be lock-nutted through. With a nipple and flange union this makes an admirable substitute for the usual plate. A hole was cut through the tank bottom in the center and the bolt-housing half of the flange union placed below. Blocking between the dunnage was fixed below this so the bolts could not drop too far. The lines were brought up to one level, all with long threads of the proper length and lock-nuts run down tight to a level. Then the cap, nipple, upper half of the flange union and gasket, all "made-up," was dropped over the ends and lock-nutted down firmly

with packing between the upper lock-nuts and top of the cap, thus insuring no out-leakage where the pipes enter.

The bolt holes of the gasket were cut as tight as possible and the whole arrangement screwed down in asphalt. The bolt ends, nuts, gasket, cap, lock-nuts, nipple and flange were thickly covered with hot asphalt. By taking off the nuts and loosening the tank pipes and upper

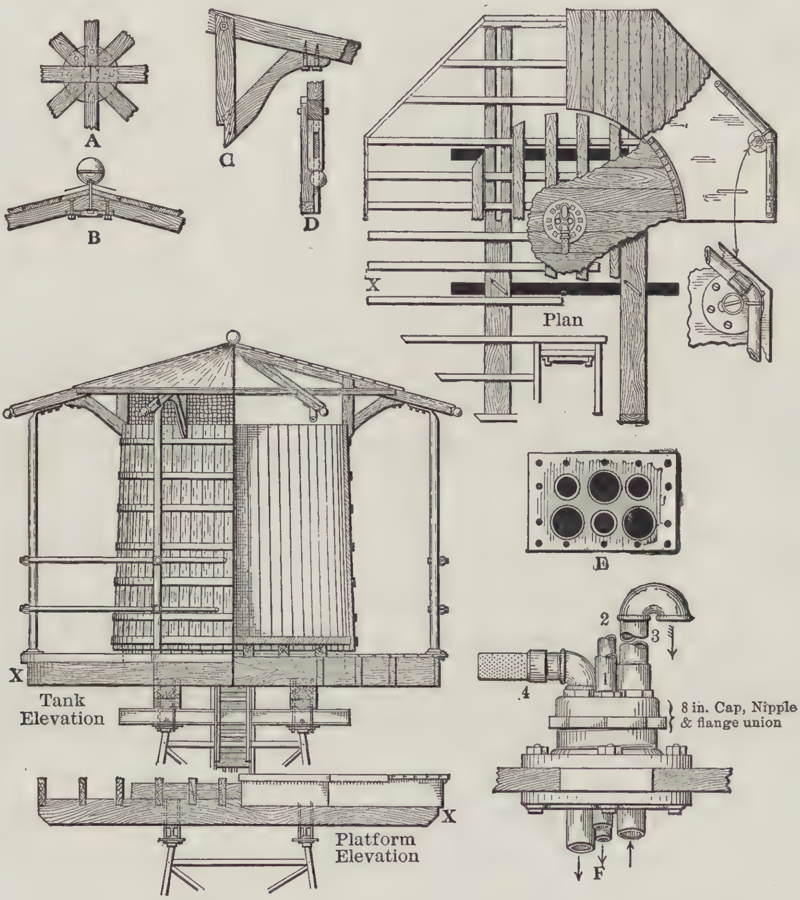


FIG. 95. WOOD TANK AND COVER WITH BALCONY RAILING ON STEEL TOWER

lock-nuts, the cap and flange can be lifted off at any time and any line repaired without trouble and without opening the frost-proof box anywhere between the inspection door near the ground and the tank bottom.

The tank water level is indicated in the kitchen by a column of mercury operating over a scale by means of water pressure from the main supply acting upon the surface of mercury in a cup into which a glass tube dips. If a gauge of this kind is improvised the scale on the

board can be penciled in by actual test. Mercury gauges of the kind can be had in the market.

Leaves, birds and insects are kept out of the tank by the crown of wire mesh shown. The trap door in the balcony floor is hinged on the tank side and fitted with cords and pulleys so that it can be pulled up from the ground before starting up the ladder and it can be pulled down again with a second cord after descending.

CHAPTER XXIX

Concrete Village Reservoirs

In order to get considerable pressure for the high levels and for aid in fire service where pumps are not kept constantly in commission or are not ample for direct pumping for fire purposes, the steel stand pipe was long the usual dependence of small places, for even where a hill was available, excavating and lining was seldom cheap work because of rock formations. Since the suitableness of reinforced concrete for reservoir walls out of ground has been demonstrated, there are many points, with sufficient elevation without substructure, where they will be used to the exclusion of steel,—only a few concrete tanks have been or will be erected on concrete stilts. The tensile strength of mere concrete is too low for use in walls above ground to make such construction ordinarily advisable, because of the cost, but, seldom crushing as low as 600 lb. per sq. in., it is when reinforced with steel rods to resist the tensile strain, cheaper in first cost than steel. It does not rot, rust, nor burn; it can be made thoroughly water-tight; its strength improves with age, and it is altogether satisfactory where conditions favor its use.

Wherever a hill of suitable elevation exists near a village, town, factory or institution, it affords a good, cheap, lasting site for a water supply reservoir:

A round shape is generally best and cheapest though the forms for such are more trouble to make than those for rectangular tanks. The cost of tank work will vary with location and price of lumber, and labor and materials for the walls. The circular tank shown is about 60000 gal. capacity, and will hold 50 odd thousand gallons below its overflow level. In this type of work, where the materials are good and the work skillfully done, the thickness of walls is largely a matter of judgment as to what will insure water-tightness with the type of reinforcing used, while the horizontal steel reinforcement is designed to resist all the tension due to the pressure of the water.

The formula for horizontal reinforcement for the reservoir shown is from Taylor and Thompson on "Concrete Plain and Reinforced."

The elements of the formula are:

H = height of reservoir in feet, above section considered.

D = diameter of reservoir in feet.

Ah = area in square inches of horizontal steel per foot of height at section considered.

fs = allowable unit stress in steel, in pounds per square inch.

The total tensile force, per foot of height, tending to rupture a

reservoir at any horizontal section, on any diameter, is 62.5 **HD**. Since the area of steel resisting this force is **2Ah**, **2Ahfs** = 62.5 **HD**, or, expressed in formula,

$$\mathbf{Ah} = \frac{31.3\ \mathbf{H\,D}}{\mathbf{fs}}$$

The comparatively low unit stress of 10000 lbs. per sq. in. for the steel was adopted in this case with the idea of preventing the formation of cracks in the concrete as it stretches under the influence of the water pressure. With this stress, as a safety factor and the reservoir being 28 ft. in diameter as shown on the sketch, by substituting figures in the formula and solving for the area of steel required at 12 ft. and at 6 ft. from the top the result is,

$$\text{At 12 ft.: } \mathbf{Ah} = \frac{31.3 \times 12 \times 28}{10000} = 1.05;\ 1.05 \div 2 = 0.52;\ \tfrac{3}{4} \times \tfrac{3}{4} = 0.56$$

$$\text{At 6-ft.: } \mathbf{Ah} = \frac{31.3 \times 6 \times 28}{10000} = 0.52;\ 0.52 \div 2 = 0.26;\ \tfrac{1}{2} \times \tfrac{1}{2} = 0.25$$

showing that $\frac{3}{4}$-in. square rods anywhere below and $\frac{1}{2}$-in. square rods anywhere above 6 ft. from the top will be ample for the horizontal reinforcement when spaced 6 in. apart as shown in Fig. 100. The amount of horizontal reinforcement necessary to take care of the water pressure at various sections will, of course, vary with the water pressure, being zero at the top and increasing toward the bottom. $\frac{3}{4}$-in. rods so placed, at some distance above the bottom and $\frac{1}{2}$-in. rods near the top will exceed the mere water pressure requirements, but it must be remembered that the wall takes the thrust of the roof rafters at the top; that some of the work or material may not be all we hope for; that a reservoir is to be a permanent fixture and one which in every sense it is best to be well on the precautionary side and that the matter of complying with figures for the various depths is not worth the trouble of handling so many sizes of rods. Besides, very small rods may easily deteriorate or become worthless from corrosion. In short, it is best, for uniformity of construction and other reasons, to use but the two sizes of rods mentioned and as indicated on the sketch.

The floor slab may be safely assumed to rest upon as good a bearing as ordinary clay. No reinforcement will therefore be required for it simply to sustain the weight of the water. The tensile strength of concrete is so low that it will, however, be necessary to place some reinforcement in it to resist the shrinkage and temperature stresses. A percentage of steel equal to 0.004 of the cross section of the concrete will be ample to resist these stresses. The cross section of floor is equal to $28 \times 12 \times 14 = 4704$ sq. in.; $4704 \times 0.004 = 18.81$ sq. in.,—of steel needed;

18.81 ÷ 0.576, the sq. in. in a $\frac{3}{4}$-in. rod, equals thirty-three $\frac{3}{4}$-in. square bars. These, if spaced in both directions, will be about 24 in. apart center to center, as shown in the sketch.

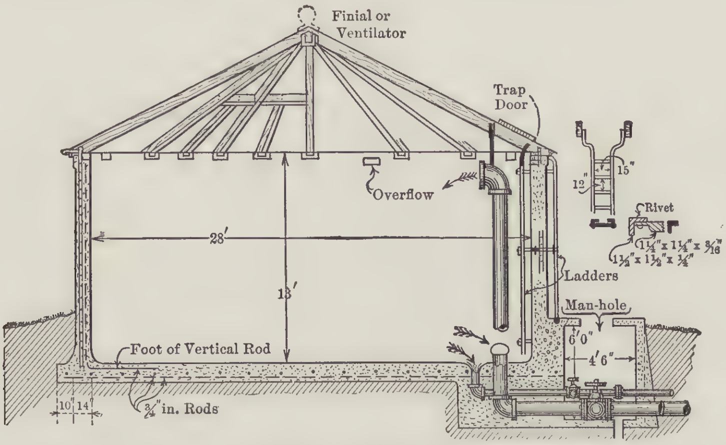


Fig. 98. 60000 Gallon Concrete Reservoir—Sectional Elevation

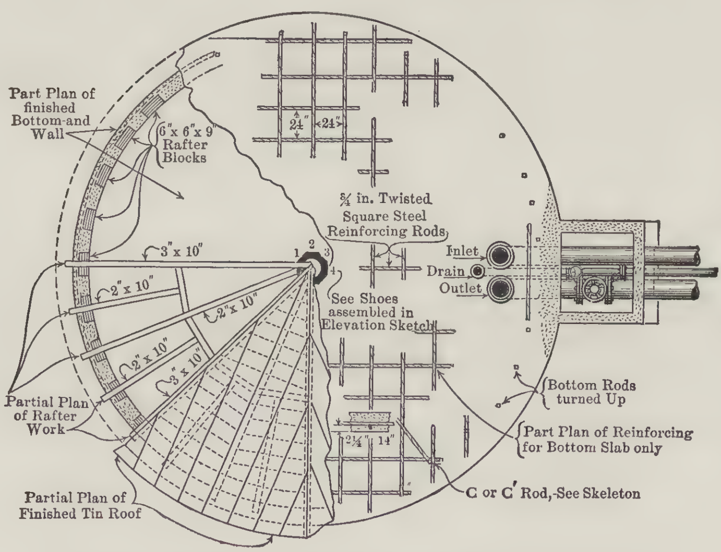


Fig. 99. 60000 Gallon Concrete Reservoir—Plan View

The least thickness of the wall near the top is 10 in. as seen in detail sketch Fig. 101. It is 14 in. thick at the bottom, while at the top a corbel construction fills it out to 12 in. in a way to act as a facia board and mold. The corbelling improves the appearance of the reservoir and also makes the wall stronger where strength is required to resist the horizontal thrust of the roof timbers.

The general elevation and plan, Figs. 98 and 99, with the aid of the

skeleton of reinforcing work, Fig. 100, and the details shown in Fig. 101, tell most of the story as to walls, roof-frame and steel reinforcement of walls and slab. The rods should be lapped 20 in. and well wired to-

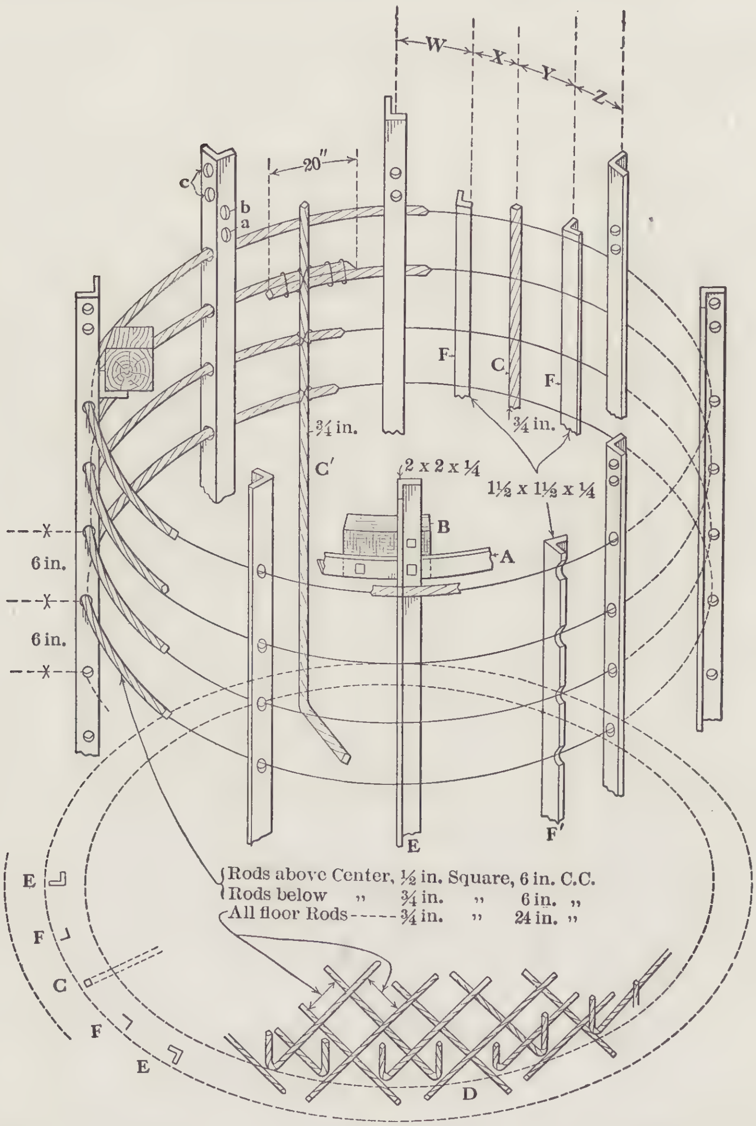


Fig. 100. Partial Skeleton of Steel Reinforcing of Concrete Reservoir

gether as on C′, Fig. 100, or held at each splice by two or three wire rope clips. The vertical reinforcement, as shown in Fig. 100, consists of 24 angles and 8 rods: Eight of these are 2x2x$\frac{1}{4}$-in. angles, **E**, spaced so

as to come at the rafters and set with the lower ends imbedded in the floor slab. A false-work or templet can be erected for these and the angles securely fastened to it so they will take the batter of the wall surface in a way to keep approximately in the neutral axis. The space between each pair of 2-in. angles is divided into 4 spaces, **W, X, Y** and **Z,** about 3 ft. each; two $1\frac{1}{2}$x$1\frac{1}{2}$x$\frac{1}{4}$-in. angles, **FF**, are set next to the 2-in. angles and in the center, a $\frac{3}{4}$-in. rod, **C**, is set with the foot turning out into the floor slab 3 or 4 ft. Angles, **F**, and rods **C**, reach to near the top of the wall. The rods **C** leave all the space between the angles **FF** for lapping and tying of the ends of the horizontal rods. Angles **E** are

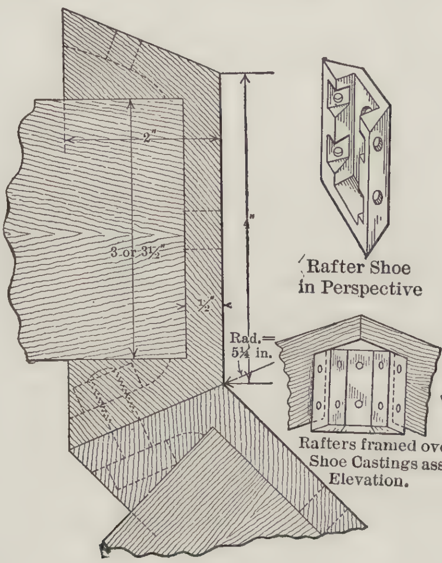


FIG. 102. PLAN DETAIL OF RAFTER SHOE

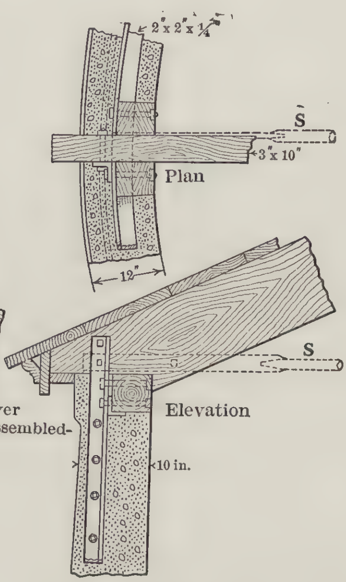


FIG. 101. DETAILS OF WORK AT TOP OF WALL

drilled and angles **F** are gapped out for the rods as shown at **F′**. The gaps make it easy to get the rods threaded through angles **E**. By wiring to the angles **F** and rods **C**, the horizontal rings of rods are kept evenly spaced and in the correct position,—an important matter in steel reinforcing. The rods should be bent to a form before placing them. In this case the center of the horizontal rods are put about $2\frac{1}{2}$ in. from the outer face of the wall. The position of the vertical reinforcement is thus fixed,—the ends for $\frac{1}{8}$-section being indicated between the bottom lines of the wall in Fig. 100.

Alternate rods of the floor reinforcing are allowed to extend into the footing projection,—the balance turn up 2 ft. more or less, as indicated at **D.**

The 2-in. angles extend above the wall so the sides of the rafter ends

can be bolted to them, as shown in Fig. 101. Blocks, **B,** imbedded in the concrete of the wall are used in lieu of a top plate. The blocks set in and are bolted to a 2x2x$\frac{1}{4}$-in. angle ring, **A**, placed inside of the 2-in. upright angles and are thus held in place while the wall work is being finished. The angle ring takes the place of one or more rods, acts as a seating and preliminary support for the blocks and helps to resist the thrust of the rafters so no heavy corbelling is necessary. If the 2-in. angles are not extended up and the angle ring is omitted, the corbelling must be heavier and reinforced, or the main rafters must be "hogged" up as indicated by rod **S** dotted in on sketches in Fig. 101. In Fig. 100, holes **c** are for the rafters; holes **a**, for the angle ring and block to attach to the upright angles, and holes **b** for the block.

A concrete of 1:2:4, mixed very wet and tamped as thrown in is satisfactory for reservoir work. The following method has been successful for additional water proofing of the interior. After the inside forms have been removed and the interior thoroughly cleaned, the walls and floor are wetted down and three brush coats of neat Portland cement, mixed to a thick creamy consistency, applied one at a time on alternate days.

For a reservoir less than 15 ft. in height, like shown, it is advisable to build the forms for the entire height at once, instead of using sectional forms. The inner side of reservoir walls is made straight and vertical. The outside is given a slight batter. Before starting to lay a new section of wall, the surface of the concrete already placed, that put in last, say the evening before, should be thoroughly scrubbed and wetted down and a layer of 1:2 mortar spread over it and rubbed into contact before placing any of the regular mixture. In order that this may be well and easily done and the material for the lower part of the wall not have to be lifted so high, the outside wall of the form can be raised (added to) as the work progresses, bracing posts of full height being set in to start with.

When sectional forms are to be used, both the inside and outside forms can be built in sections 4 to 5 feet high and about 6 feet in length. Such forms may be constructed of 2x8-in. horizontal ribs spaced 24 or 30 in. center to center and 2x6 in. vertical ribs at 3 ft. centers, using $\frac{7}{8}$-in. sheathing over them. The adjacent sections should be bolted together through the ribs and 4x4 in. or larger posts set vertically about 6 ft. apart both inside and outside, and wired through the forms which are drawn up against spreaders to the proper position. The top and bottom edges of the form sections should be beveled so as to form a tight joint and leave a smooth surface between the successive courses.

If concrete is to set for several weeks before removing the forms it is not necessary to give them the usual preliminary coating of crude

oil or grease on the inside, as the cohesion of the concrete will then be greater than its adhesion to the lumber. It is proper though, when not oiled, to thoroughly wet the planks before laying the concrete against them. A reservoir like shown should stand 40 to 50 days before being filled with water. The walls and bottom thickness given is about 20 per cent. heavier than is ordinarily figured.

It is well to bear the following in mind regarding concrete work:—Portland cement, clean sand, and clean rock broken to $1\frac{1}{2}$ or 2-in. mesh should be used in the walls. Portland cement is acid proof, sets slowly enough to work without haste, and incloses the other materials from the elements so they cannot deteriorate. The harder the rock the better. Gravel makes a good concrete and is far better than poor rock. The quality of sand is not so important, but it should be clean. Altogether a weight of water equal to that of the cement used will be needed. Rock or gravel is merely a bulk producer with a crushing strength high enough to make a sound wall. The sand, or gravel and sand, used with rock serves to fill the voids between the rock sprawls. The cement is a binder. Broken rock contains 40 to 50 per cent. voids and sand from $\frac{1}{3}$ for fine to 40 per cent. for coarse grades. The percentages of gravel sand and cement are roughly based on the voids. If the voids of rock be taken at 50 and those of the sand at 40 per cent. about 45 cu. ft. of material,—27 cu. ft. rock, 13 of sand and 5 of cement, theoretically make a cubic yard. In practice, the ingredients are all held apart by a coating of cement and 45 cu. ft. of material exceeds a yard of mixture. From 4 to $5\frac{1}{2}$ cu. ft. of cement per cubic yard are used in what is termed 1:2:4 mixture,—usually about 5 cu. ft.

On account of the dampness always below a roof covering water, roof beams are generally made very heavy and well protected by some preservative before placing. The roof shown is much lighter than usual. In districts where heavy snows are frequent the main rafters should be at least 4x10-in. or 3x14-in. and those setting between 3x10 or 2x14-in. Instead of the usual one-piece center casting, a center piece can be made up of sections like shown in plan, perspective and elevation, Fig. 102. The cost of the pattern for a shoe of that kind is very little. The rafters can be framed over the shoe ring or the center can be left open for a ventilating finial.

An angle iron ladder is anchored to the wall inside and outside as indicated in Fig. 98.

The delivery pipe discharges high up. The service main should project 6 in. or more above the floor to avoid sediment and ought to have wire netting over it. The floor should slope a little to a drain pipe and have a depression at its mouth, as shown in the sketch. The valves for the drain and service main are protected from frost by a

valve well just outside the reservoir wall, made as shown. Where the pump delivery main is large, a rectangular overflow opening like shown, permits getting the bottom of it higher up than when a round opening is made.

CHAPTER XXX

Effect of Weather on Outside Tanks

What are the effects of frost in an outside covered wood tank with staves 2 in. thick, diameter, 8 ft., and height 10 ft., containing water 8 ft. deep. 8x3.1416 approximate equals 25 ft. circumference, which, by 8 gives 200 sq. ft. of cylindrical surface. $8 \times 8 \times .7854$ gives 50 sq. ft. end area; taking the top and bottom radiation at half the value of the exposed side surface and not considering the wall surface above water, the effective radiating surface of the tank may be taken as 250 sq. ft. The coldest water likely to enter any tank would be well water, at, say 50 deg. F. Taking freezing point, 32 deg. F. as the ultimate minimum: $50+32=82$, which, divided by 2 gives 41 deg. F., mean temperature of the water cooling. Assuming zero F. weather, there is therefore 41 deg. difference between the air and water *mean*, which, by .5, (an arbitrary mean thermal unit factor of radiation for wood 2 in. thick per square foot per hour per degree difference between the temperature of the water and that of the outside air) gives 20.5,—for safety, say 25 B.t.u. loss per degree difference per hour per square foot of tank surface. Hourly loss per square foot, in heat units, equaling 25, 25×250 (square feet surface in tank) equal 6250 B.t.u. loss per hour for the tank in still zero air,—wind materially increases the loss of heat. Next, considering the heat possible to be lost: one British heat unit added or abstracted being the amount of heat that will raise or lower one pound of water one degree F., there is (taking the tank as a cylinder: area, 50 sq. ft., and depth of water 8 ft.) 400 cu. ft. of water contained, which, weighing 62.5 lbs. per cubic foot makes 25000 lbs. of water, and, a loss of 25000 heat units is therefore necessary to change its temperature 1 deg. F. If the water to begin with is 50 deg. F., 18 deg. loss will lower it to a point where the latent heat of fusion begins to become sensible; $25000 \times 18=450000$ heat units loss necessary to reduce the water to 32 deg. F. Before ice can form, however, the latent heat of fusion, 144 B.t.u. per pound, for all that freezes, will have to be extracted. To turn the contents of the tank to ice from water at 32 deg. F. would require an additional 3600000 B.t.u., or a total of 4050000 B.t.u. to reduce 25000 lbs. of water to ice at 32 deg. F. Dividing 6250, tank loss per hour, into 4050000 gives 648 hours, or 27 days to reduce the water from 50 deg. to 32 deg. ice; the same divided into 450000 gives 72 hours or 3 days to reduce the water to 32 deg. F.

The same deductions can be made in the same way for any other

size tank and other conditions of weather by substituting dimensions and other data to suit the occasion.

If the tank be iron, 1.7 B.t.u. per hour per square foot per degree difference between air and water, should be employed in place of the factor 0.5 used here for wood. Figuring on the foregoing basis for an iron tank give 25 hours to reduce the water to 32 deg. F. in zero weather, and 216 hours, or nine days are yet required to turn the water to ice.

Tanks are seldom figured for less than two days supply. If filled at evening, they have the better advantage of distributing the loss over night throughout the whole contents while the water is warmest and the second night begins with a higher temperature, if the sun shines during the day, because the water-backed surface is greater and the warmest water remains up, even to surface until the contents fall below 39 deg. F. If the contents reach 32 at night, static conditions may prevent ice, and if some is formed, fresh water being pumped in will float it in the warmest of the bulk. In an upright cylinder or rectangular tank, lowering the level of the water reduces the water-backed radiating surface proportionately, though the exposed surface per contents is less in cylindrical than in other forms. The larger the tank the less the percentage of exposed surface in cylinders, and in rectangular tanks too, unless there is great difference in the width and breadth.

Very little of the whole country is subject to long spells of zero weather. Wood tanks and protection are available when necessary. In most cases fresh water renewing the supply, warmth in daytime, and the short duration of very severe weather make special protection of even iron tanks unnecessary. When freezing occurs, the expansion of sheet or surface ice is often the most damaging and this may be largely prevented by floating chunks of cedar, or white pine in the water,—wood that will not decay easily or leave unpleasant taste in the water and finally fill it with bits of doughy wood, etc. A heavy piece or two, 4x4 in., say, submerged endwise, are good to help compensate for the change in bulk as the quantity of water reaching 32 deg. increases under sheet ice. If left with no means of compensation the strain at the surface and under thick sheets of ice are both very severe on the tank.

A little ice in an outside tank need not alarm the owner; it acts as an equilibrator of no mean order,—5 cu. ft. in an 8x10 ft. tank is equal to 7 hours total heat loss for zero weather. If the weather becomes colder, the invisible bulkless latent heat, 144 B.t.u. per pound, must be given off before further solidification can take place.

CHAPTER XXXI

Frost Breaks

Running service pipes exposed in cellar huts, light and air grate pits, etc., is poor practice, unless the work is being done in a warm climate, yet examples of such work are not rare. In some cases the pipe is left bare, leaving the charge of draining on some one every cold night, if it is not frozen before night; in other cases such lines are placed in covered channels or boxed in.

A pipe can be boxed and packed about so it will not freeze but the cost is usually greater than that of a better method,—building two or three boxes around the pipe, one within the other. Air spaces between the boxes, and covering each box with water-proof building paper before the cleats for the next one are put on are essential. One or more boxes filled with mineral wool, felt, or other suitable material, placed about the pipe are also trustworthy. The locality, and material available, may determine which plan will be followed. Sometimes a combination of the two methods is good. If an upright box is filled, horizontal divisions must be fitted in at short intervals and the filling carefully packed; if not well packed, the filling, even in one foot depth, will settle and leave some of the pipe bare; if the divisions are omitted, the filling will soon settle and expose a big space at the top. Frost-proof boxes must be permanently tight enough not to "leak" the filling. No matter how carefully the filling may be placed, it is a good plan to first cover the pipe with thick felt or other good covering to guard against possible exposure by settlement, or frost effects from insufficient box area.

Fig. 105 shows a stop and waste cock just inside the cellar hut wall at the regular service pipe depth (frost depth). This controls all the pipe in the house, but if exposed, the service may freeze by conduction, on the street side of the cock, even though the house pipe is drained. A stop and waste cock at **A**, Fig. 105, does not serve its normal dual function,—instead of wasting the service pipe water *out* at the waste hole when the water is off, air goes in, permitting the water to drain out,—if a waste cock is opened at the lowest point, as at **B**. When one cock must be shut off and another (the drain) opened, the drain is frequently forgotten, especially if the work is in a district where the people have been mostly accustomed to combination cocks. For this reason the arrangement shown in Fig. 105 is not good, and with it, as shown, the drain is too often placed where it will be found covered and inaccessible when necessary to use it.

To drain a pipe, the water must be shut off, tight, a drain (of the cock itself or a separate cock) must be open, and the atmospheric pressure must be admitted at high points,—by opening faucets, air valves or whatever is provided. In Fig. 105, air would go in at faucets and at cock **A**, and the water would run out at **B** and sink in the dry-well **C**.

Near the stairs—or some other place that will always be reachable—as at **Y**, is a better location for a drain cock than **B**; in fact, if the pipe is all properly protected, **Y** is a good point to place an iron stop and waste box—one including the stop and waste cock at the bottom and having a slotted swivel head with check-pin at the top,—as shown. This makes the separate waste cock **B** and its box unnecessary. If rules, or arbitrary specifications require the shut-off cock to be at the front, an iron box, as at **Z**, can take the place of cock **A**. Sufficient air to permit drainage will find its way to the cock through the box and otherwise. Such a box is as easily repaired in this location as in any other and is no extra trouble to install if the work is done while the service ditch is open

Unless the excavating is to be done in rock, a far better way than running a service inside where it will have to be boxed to prevent freezing, is to carry it down outside the hut wall and under the foundation to below frost depth in the hut, as indicated in Fig. 105. By drilling down while the service ditch is open, and tunneling or drilling under from a trench in the hut floor, as shown by the dotted lines, either a lead or iron line can be run in with less expense than is necessary to carry it through the wall and down inside as shown. A lead pipe is shown by dash lines in the drill holes in the sketch. If the pipe used is lead, it is poked down from above and worked out by hooking it forward from **X**. The upright piece of an iron service can be screwed up from the service ditch. The pipe in the hut floor trench offers no difficulty if there is a good clean elbow on the lower end of the upright, and the ell is stopped so it points into the trench. The ell can be kept clean by loosely plugging while the upright is being screwed up, and it can be stopped straight, by watching or by stopping by a mark at the upper end, made for the purpose.

The drill holes may be made with a plumber's dirt drill, bored with an earth augur, or made with a post-hole digger. A hole of any reasonable depth can be made with any of them in clay, earth, sandy loam or loamy sand. No strata that a drill or digger will not lift is likely to be found at cellar depths. The service is usually from 3 to 4 ft. or more below the surface, leaving a distance to be drilled not more than a digger handle will reach, even if the first floor is close to the ground, as in a store building. If a service is drilled in from the corporation box hole, a hole must be dug at the hut wall in order to put in the upright pipe and box,—if the box is to stick through the hut wall. Augur stems can be lengthened out as required. If there is occasion to drill

deeper than an extended drill stem can be managed, only enough stem to give a sinking weight need be used, for, by passing a sash cord through the stem or knotting it in the slot of the drill at the socket and making several half-hitches up the handle, it can be handled to any depth the material a drill will hold extends down to. If a hole larger than the dirt drill will make is wanted and there is no augur at hand, a common spring post-hole digger can be made to work to any depth by tying a line in the fork at the lower end of the handle and half-hitching it up the handle as before mentioned.

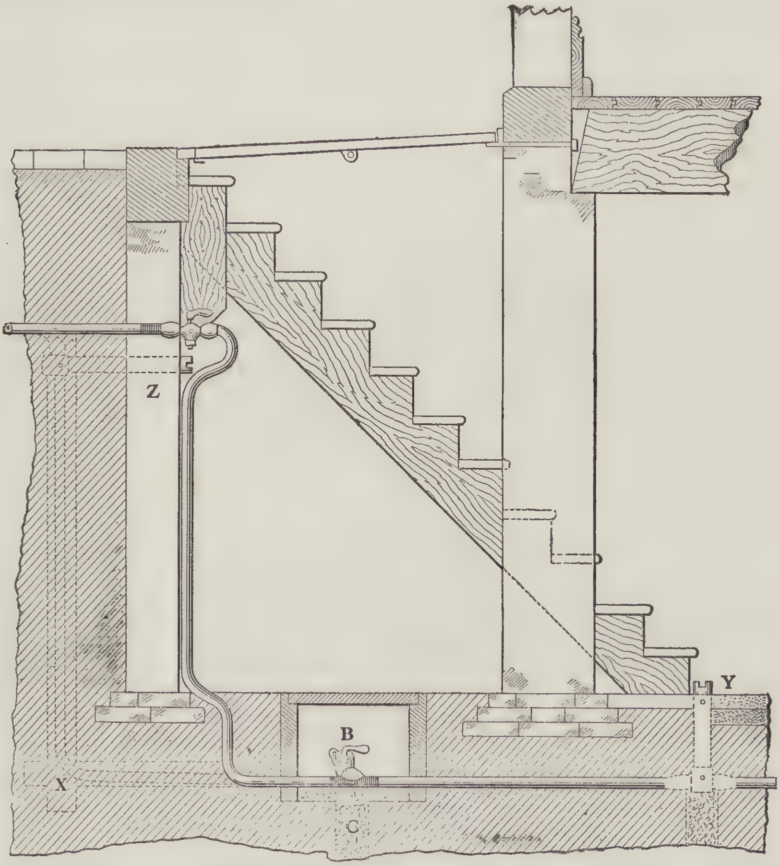


Fig. 105. Exposed Service Pipe

The dry well under **B** or **Y** can be made with any of the above tools. The well should be worked down to coarse sand, at least. The hole may be filled with fragments of hard brick or rock dropped in carefully to avoid choking the hole above the bottom. If the hole is large enough, hubless tile may be put in and the interior then filled or not as preferred. Filling is doubtless the best, as driftings through the joints are not so

likely to plug the bottom to above the seepage strata and there is less chance of losing, beyond recovery, a nut, washer or plyers when working around the open hole.

To avoid breaking the tile in the hole, it must be lowered with a stick or a wire passed through the tile and bent under the lower edge, but not hooked up enough to prevent twisting it out from between the tile ends after the joint is seated. A long strip of wood will answer in place of wire by putting a nail or screw in the side or edge near the end, for the pipe to stand on. If it is feared the joints may slip off of the nail, a short stick with a cord tied to it can be wedged across the pipe from the long stick to the opposite wall of the pipe. This will hold the joint against the long stick so it cannot slip off while lowering; when the joint is seated, the short stick can be jerked out of place and drawn up with the string and the long piece will twist the nail or screw out from between the joint ends.

Notwithstanding the cost of repairs, the vigilance of house owners, the advance statistics as to probable temperatures furnished by the weather bureau, and the strenuous efforts of the craft and the architects to make plumbing work immune from frost, the "frost burst" repair items is still a considerable factor throughout the severe weather season in many localities. Such work is not by a great deal the result of poor or careless plumbing,—good work is not always given proper attention; heating jobs sometimes come to grief for a short spell; some portion of the building fails of being heated or finished as specified or intended, and so on, and the plumber generally bears the brunt of the ill humor following.

Some very interesting things occur from pipes unexpectedly freezing up. Water expands from 39 deg. F. to freezing point, 32 deg. F., and then makes a further material increase in bulk as the water at 32 deg. F. changes to ice at 32 deg. F. The expansion from maximum density, 39 deg. F. or 4 deg. C. to freezing is too little to consider in pipe freezing problems, amounting as it does to only about 0.00012 volume, but the expansion of water at 32 deg. F. to ice at 32 deg. F. is about $8\frac{1}{2}$ per cent., giving 32 deg. ice of a specific gravity of about 0.927,—$57\frac{1}{2}$ lb. per cubic foot—,the Specific Gravity of water at 62 deg. F. being equal to 1.0. Water at 62 deg. F. weighs about 62.35 lb. per cu. ft. and is commonly taken as 8.3 lb. per U. S. gallon (231 cu. in.),—7.5 gals. of water being, for all ordinary purposes, considered a cubic foot. This data gives a basis on which to consider the effects of frost on plumbing work.

Let a service something like shown in Fig. 105, be taken as an example, and assume there is 6 ft. of 1-in. pipe, filled with water under active pressure, exposed to low temperature and that 24 in. of the pipe freezes solid. The area of 1 in. $= 0.7854$; $.7854 \times 24 = 18.85$, say 19 cu. in.;

.085 equals the per cent. expansion; $19 \times .085 = 1.62$ cu. in., the increase in volume of the portion of contents frozen; $1.62 \div 0.7854 = 2.06$ linear inches of 1-in. pipe the increase in volume frozen will fill, if the whole increment extends longitudinally in the pipe. If cooled and frozen all along and all through, at once, diametrical expansion would perhaps prevent core extension of the ice much beyond that due to simple linear expansion,—0.0000583 of the unit length per deg. F. But, one end of an exposed place almost always freezes solid ahead of the balance and a

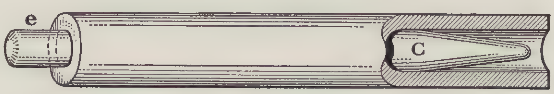


FIG. 106. THE ICE CORE IN FROZEN PORTION

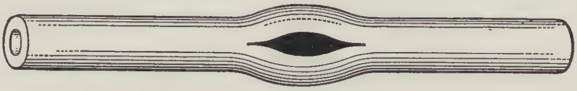


FIG. 107. A LEAD PIPE FROST BURST

skim of ice forms along the interior of the balance of the chilled wall, to which other layers are added. One end being solid, the increment of volume makes room for itself by and large. Experience shows, however, that the ice core is principally built to in the direction of the fixtures, and in a way, aided by the resistance of the pipe wall, to crowd the liquid contents on the house side and thus bring abnormal pressure against the pipe and faucets of the house, unless there is leakage or a liberal distribution of air chambers on the supplies. The house end of a frozen pipe generally shows an ice core pointing into the bore somewhat as shown at **c**, Fig. 106, in which **e** has no significance beyond indicating ice in the pipe.

When a portion of a service pipe freezes, there must, if the pipe is lead, be air space or leakage to prevent bursting. In the absence of other relief for the extra contents being crowded in by the expanding ice the pipe invariably swells out somewhat egg-shaped at the weakest point. If the ice expansion is sufficient, the wall of the pipe is ruptured as shown in Fig. 107. A burst of this kind is easily repaired without supplying any new pipe, unless it has often before been so bursted and repaired. If a pipe happens to be frozen at two points, there is little chance of relief and the pipe is most certain to be bursted,—at the weakest point, never, however, in a joint on lead pipe nor at a point on such, the freezing of which causes the burst to occur. It requires repeated freezing and thawing to weaken a lead pipe, to the point of failing, by diametrical expansion of ice.

All frost ruptures take place during the process of freezing, yet

many people will argue with a plumber, saying the break occurred while they were applying heat and was due to warming the frozen pipe. Thawing the core of ice loose from the pipe wall permits pressure leakage, if the water is on,—this is what leads ignorant people to believe that heat instead of lack of it bursts their pipes.

When an iron pipe freezes it always splits, generally at the weld, from end to end of the frozen portion, and sometimes further,—its brittleness and contraction due to lowering temperature and the diametrical expansion of the ice being more than its elasticity will stand.

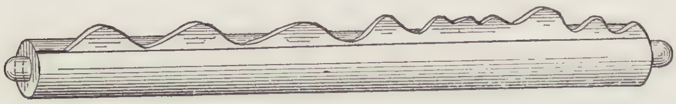


Fig. 108. Effect of Freezing Water in Iron Pipe

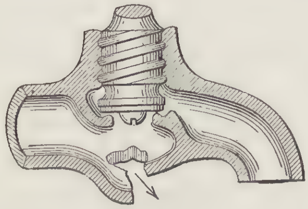


Fig. 109. Frost Break in Compression Faucet

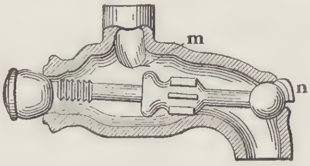


Fig. 110. Frost Break in Fuller Faucet

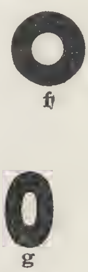


Fig. 111. Oval and Circular Sections

A section of iron pipe showing ice protruding from the ends and from a split along its length is shown in Fig. 108.

Some examples of faucet frost breaks are shown in Figs. 109 and 110. The break in Fig. 109, of a compression faucet, is typical of the results of freezing at the faucet alone, but the rupture may occur where shown, or anywhere back of the washer as the result of the service freezing at some distant point,—depending on whether the pipe or the faucet will stand the greatest strain.

Faucets of the Fuller type are seldom damaged in the body by the freezing of pipes, as the body contains no water when the faucet is closed. A break that illustrates the force exerted when water freezes, is shown in Fig. 110. The service was frozen under the house some 40 ft. away from the faucet; ice extension in the bore of the pipe crowded the water with such power as to strip the washer stem threads, drive the ball stem through the ball, shear off the eccentric pin on the end of the handle shaft and jam the end of the ball stem through the nose of the faucet at the front, as indicated at **n**.

In Fig. 111, is a circular (**f**) and an oval (**g**) section. Many persons have been serious in the belief that a pipe with section like **g**, would not burst from water freezing in it. An oval form *does* tend to round up

under interior pressure because the oval contains less area than a circle of equal circumference, but this fact is of no practical value, even were all water pipes to always be made of lead.

Examples of the effect of frost could be sighted without end, but enough has been said to enable any reader to interpret such effects as may occur in his own experience.

CHAPTER XXXII

Freezing Pipes for Repair Work

One job that falls to the lot of the plumber too seldom, in most localities, for an apprentice to gain a fair knowledge of the proceedings, is that of freezing lead water pipe in order to stop the supply while repairs are made. Necessity for freezing a pipe may occur in several ways. The stop in a cellar or area may be blocked with merchandise; a frost damaged stop cock may fail to stop the water, or water may be necessary to part of a job while another part is changed or repaired. It has been found expedient to freeze the service in such cases for the purpose of repairing or putting in a new cock but, replacing leaky corporation cocks furnish more examples of such work than any other cause. A lead pipe can be hammered "shut" to still the water. The closure for house leakage must be made on the house side of where the cock is to be placed.

It is useless to attempt to freeze an iron pipe for repairs as it will split at the point frozen.

To get a block of ice and a bucket of salt and freeze a pipe in order that we may branch into it, renew a cock, or repair a pipe, which, for any reason we cannot stop the supply to, is a job that most of us usually perform without much ado, though we fall down now and then and call it "ill-luck." The same factor is behind the failure of most "ill-luck jobs,"—a good reason, (something not provided for) which, in "freezing" jobs may be any one of many things,—leakage through the pipe; more metal and ground water to be cooled than estimated on; scattering the mass of ice too much; freezing too close to where the heat must be applied; fooling with the joint too long instead of wiping it promptly, etc.

No figures are ordinarily made for practical work, but it is wise to be able to estimate roughly, the required refrigeration. It is an interesting and instructive way of keeping in touch with data essential to other problems. To merely go over the necessary figures, without explanation to another is quite rapidly done, being, to a great extent, purely mental work, but it is not so quick and easily put into black and white in an understandable manner.

As an example, what amount of heat must be absorbed under the following conditions?

A pipe in earth is to be frozen. It is assumed that the following materials would have to be chilled more or less: 1 cu. ft. of earth weighing 118 lb.; water in the earth, 20 cu. in.; water in the pipe 10 cu. in.;

lead in the pipe, 4 lb.; solder (lead and tin), 1 lb.; brass cock (zinc and copper), 1 lb.; air in the trench, 20 cu. ft.; temperature of the weather, 100 deg. F.; temperature of the earth, metal and water, 50 deg. F., and the working temperature of the frozen portion of the pipe to be 15 deg. F.

The amount of heat to be extracted from these materials equals for each, the weight multiplied by the specific heat and by the number of degrees it is to be cooled. The specific heat of water as liquid and as ice, and the latent heat of solidification are each factors in determining the heat to be absorbed from the water.

With water as 1.0, the specific heat or thermal capacity of the other materials mentioned may be taken to be: solid lead, 0.03 that of water; tin, 0.056; zinc and copper, 0.095; brass, 0.094; ice, 0.504; air, 0.23, and earth, say at the liberal figure of 0.2. The cooling resistance of the materials affected roughly traced, is then, as follows: Each pound of earth will give up $\frac{1}{5}$ as much heat as 1-lb. of water, in cooling 1 deg., therefore, $118 \times 0.2 = 23.6$ B.t.u. per degree cooled. $50—15 = 35$; $35 \times 23.6 = 826$ B.t.u. The degree of earth cooling at different points will vary say to equal cooling the mass through $\frac{1}{4}$ of the working range,—then $826 \div 4 = 206$ B.t.u. to cool the earth.

To cool 20 cu. in. of water in the earth and 10 cu. in. of water in the pipe, from 50 deg. to 15 deg. plus requires: first, $50—32 = 18$ deg. range in the liquid. As 231 cu. in. equal 1-gal. and 1-gal. weighs 8.3 lb.; 30 cu. in. equal 13 per cent. of 1 gal. and 13 per cent. of 8.3 lb. equal 1.08 lb.; $1.08 \times 18 = 19.44$, B.t.u. to lower the temperature of the water to freezing, or 32 deg. F. At 32 deg. the latent heat of liquification or solidification must be taken care of. This amounts to 144 B.t.u. per pound of ice melted or water frozen, and to change 1.08 lb. of water at 32 deg. into ice at 32 deg. requires $144 \times 1.08 = 155.52$, B.t.u. to freeze the water. Then, the ice must be cooled from 32 deg. down to 15 deg. Its capacity for absorption is found thus: $32—15 = 17$ deg.,—the range of ice cooling; 0.504, the relative thermal capacity of ice, multiplied by 1.08 equals 0.5443; $0.5443 \times 17 = 9.25$ B.t.u. to chill the ice.

The specific heat of brass may be taken as that of copper,—0.095. 0.095×1 (1-lb.) $= 0.095$; $0.095 \times 35 = 3.32$ B.t.u. to cool the brass.

To cool 4 lb. of lead there will be required, $4 \times 0.03 = 0.12$ and $0.12 \times 35 = 4.2$ B.t.u.

Taking the mean of 0.03 and 0.056, or 0.043, as the specific heat of the solder in the cock joint, $0.043 \times 1 \times 35 = 1.5$ B.t.u. to cool the solder.

Next, assuming 20 cu. ft. or air to be chilled, through the range, in the trench; the specific heat of air being 0.23 plus and in the neighborhood of 13 cu. ft. per lb., the air to be cooled may be taken to be 1.5 lb.; 0.23×1.5 (lb.) $= 0.345$; 100 deg. air temperature, minus $15 = 85$ deg., the range to be cooled through, and $85 \times 0.345 = 29.3$, B.t.u. needed to cool the air.

These amounts total 428.5 B.t.u.,—less than 3-lb. of ice will absorb in melting from 32 deg. ice to 32 deg. water. This amount will not freeze the pipe—much adjacent material, not above considered, gives up heat to the ice doing the freezing and, just the weight, condition and extent of material that will be cooled cannot be judged correctly. For these features the calculated weight of ice might be added, making 6 lbs., and as the freezing temperature must be continued throughout the work, the amount should at least be doubled again, making 12 lbs. In case of "ill-luck,"—a chunk of dirt caving in and disturbing the ice, some water leaking through and not at first noted, etc.,—may double the whole amount again,—twenty-four pounds not being more than needed. In fact it is never worth the risk to get less than 20 or 30 lbs. of ice,—5, 10 or 15 cents worth, according to the price of ice.

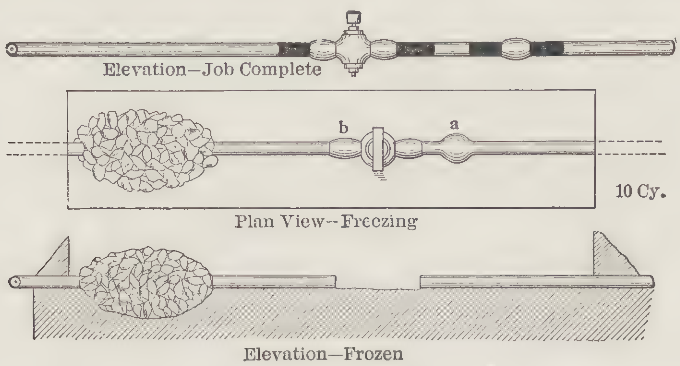


FIG. 112. FREEZING A PIPE TO RENEW A STOP COCK

The action of the salt and ice may be understood from the following: quick action is needed for freezing a pipe. It is a property of chloride of sodium (common salt) and water that it will not freeze solid above zero F., and of ice and salt, that the ice will melt and the mixture remain liquid or slush at temperatures above zero. If zero ice could be laid about the pipe and so kept in contact with it, the water would soon freeze, but this is not practicable, so salt is mixed with broken ice to obtain a low temperature quickly. The salt forces the ice into a liquid state more rapidly than the liquid can take up the amount of heat corresponding to the weight of water liquified and the temperature of the general mass falls more or less, according to the absorption and rate of liquification.

In Fig. 112 is a plan view, and below it an elevation, showing the position of a defective stop cock and a mass of broken ice and salt surrounding the pipe about as would be the case where a new stop cock is to be wiped in. The old cock permits water to by-pass the core and the drawing of water at some point in the house might therefore thwart

the work, so the pipe is hammered "shut" near the cock, as shown at **a**. The ice freezes the pipe within its mass. There is room enough between the ice and **b** to prevent conduction from thawing the ice while the cock is being wiped in. When frozen, the pipe and cock from **a** to **b** more or less are cut out and the ends prepared; the cock, wiped to a piece of pipe is tinned and made hot, and at the last minute the frozen end is gently bent (offsetted) up some to prevent water creeping to the solder; the cock is then set, well heated, with the core out, and the joint wiped quickly; the pipe and cock are cooled with water after a little, the cock wiped out and the core, lubricated, set and secured. The piece can then be wiped to the house line at leisure, as the cock controls the pressure. If the ice in the pipe does not thaw quick enough of its own accord, heat can be applied. Diametrical expansion of the core of ice in the frozen part will not harm the pipe if it has not been previously damaged.

CHAPTER XXXIII

Village Water Systems

Many plumbers are as well equipped in some respects to install a small water works as a few of the men who are following that business and a brief mention of the leading points to be considered may enable a local plumber, with the aid of his native talent, to undertake such work in his vicinity.

The pipes must be laid below frost and traffic disturbance, usually 4 ft. deep. Cast pipe is the best for mains; the joints are tightly yarned, filled with lead at one pouring and calked hard. The reservoir may be of any of the usual materials and somewhat larger than immediately required, basing the capacity on 125 gals. per person per day and to hold two or three days supply. The main pipes should never be less than 6 in. unless the people to be supplied are less than 1000 and well concentrated. The fire hydrants should take $2\frac{1}{2}$ or 3 in. hose, and each should have a dry well to soak up the waste water. The source of supply may be any stream, any properly kept water shed, or a series of tubular wells, according to location. The pumps may be any of the triple or double acting forms, of ample size,—if to pump for fire service they should be duplex, and fitted in duplicate.

The most ordinary fire protection is better than none. If the available money is limited, one set of mains will answer for domestic service and fire protection. Two-nozzle hydrants not more than 100 yard apart should be put in central districts,—in the outskirts hydrants may be placed further apart. The pumps should be large enough to supply 4 fire streams at once. The character of the intake well will depend upon local conditions. In some cases the pumps may have to be set in a tight well—protected againts flooding—in order to be within the suction limit in low water and not be drowned in high water. Ordinarily a well something like shown in Fig. 114, deep enough to take water from the stream in low water and high enough to confine the high water level, will answer. With a well, no drift wood or current has to be contended with and the suction water is clearer, but sediment in the well must be taken care of. If the suction is properly extended into the stream, the sediment gives little or no trouble, but drift and current must be braced against.

With regard to the effectiveness of the plant in use, the cost of domestic service fitting, economy and certainty of operation and quickness in getting ready for fire service, a number of things must be carefully weighed in each case. If electric light is to be supplied in con-

nection with the plant, steam can be used day and night, filling the reservoir during the day and making current to light the town at night. With this plan in operation, there is always steam power ready to start pumps without delay and an attendant is always on duty. If light is not supplied steam would be too expensive, for it would not do to wait until a fire breaks out to get up steam, and to keep fire and attendance day and night for water pressure only is too costly for a village.

The cheapest maintenance is probably a gasoline power plant in which the reservoir is arranged to give domestic service pressure at all times except when the pumps are operating for fire service. In this, the pumps deliver to the reservoir high up through a separate main used for no other purpose; the domestic service and fire hydrants are on the same and only set of street mains; the street main system feeds from the reservoir through a check valve in the valve well, and a full size main is extended to the power house and connected to the pump delivery. When a fire occurs, the hydrants are fed by reservoir pressure until the engine is actually operating the pumps and throwing water into the reservoir as usual,—the delivery from the pumps is then switched from the reservoir delivery line to the town street main system which also feeds all fire hydrants. The check valve on the domestic service main at the reservoir then holds the pump delivery back from the reservoir and the full pressure of the pumps less domestic leakage and usage is effective.

Another arrangement is outlined in Fig. 114. It is more expensive but has some advantages. It operates as follows: a high up delivery to the reservoir is regularly made through the main shown in solid line; to it are connected all the fire hydrants; all of the diaphragm valves are open, and all the common valves shown may be open when pumping. The back flow on both lines must be controlled at the pump by common or check valves when the pumps are not at work. Normally the fire system is under reservoir pressure by feeding into it from the domestic system, through a cross connection in the power house as shown, or at some other point. When a fire occurs the reservoir pressure is available until the engine is under way. The fire system and the domestic system are open to the checks on the pump delivery. The air pressure in the accumulating tank, if not always kept under pressure, soon reaches a point that will operate the diaphragm valves.

The engine may be thrown into gear with the pumps immediately if desired, and the air allowed to close the delivery to the reservoir, to the cross-connection between the systems and to also shut off the diaphragm valve on domestic system near the pump as soon afterward as the pressure will act. Fire pressure is then on to all of the fire hydrants; none of the pump delivery can get into the reservoir nor into the domestic system; the domestic system is supplied as usual by the reservoir

during a fire and the plumbing pipes, fixtures, street mains, garden hose, etc., are never subjected to fire pressure. The full force and volume of the pump delivery is effective in this way for fire protection because the item of loss due to persistent domestic usage (contrary to rules during

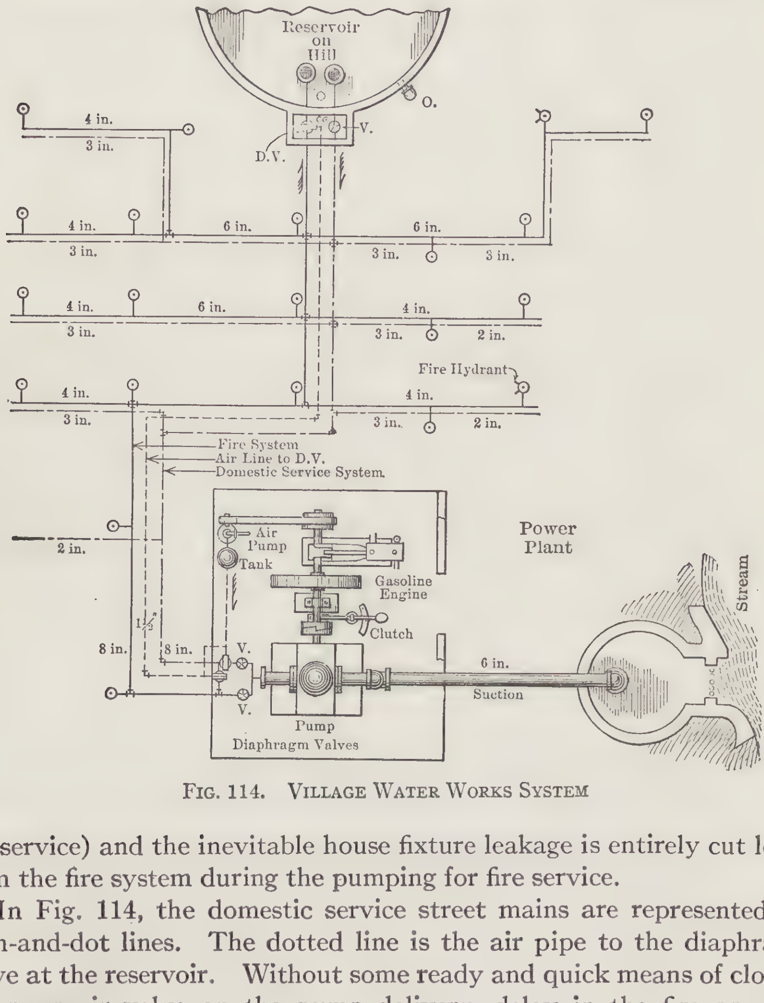


FIG. 114. VILLAGE WATER WORKS SYSTEM

fire service) and the inevitable house fixture leakage is entirely cut loose from the fire system during the pumping for fire service.

In Fig. 114, the domestic service street mains are represented by dash-and-dot lines. The dotted line is the air pipe to the diaphragm valve at the reservoir. Without some ready and quick means of closing the reservoir valve on the pump delivery, delay in the fire pressure would occur as it would be impracticable in small places to keep an attendant at the reservoir for the specific purpose of closing the valve.

CHAPTER XXXIV

Data as Aid in Estimating Cost of Street Pipe Work

Brief data concerning common cast water and gas street main pipe and fittings is often valuable to tradesmen, especially those doing business remote from large cities. Village and community systems of mains do not require, in most cases, the careful preliminary engineering essential to large plants. It is not intended that this statement should be understood as recommending careless work,—to pipe a job with sizes certain to be amply large may be cheaper than to spend a portion of the money available in determining to a "frazzle" just what will barely answer the demand, whether some provision for the future is considered or not. The information in Table XXII and otherwise herewith is quite as valuable for what it will suggest, to those who do not often estimate on such work, as it is for its specific character.

Table XXII. Cast Water and Gas Pipe Weights, Joint Materials, Pressures Suited for, etc.

Size inches, inside diameter	2	3	4	6	8	10
Water pipe, thickness, inches	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{9}{16}$
Water pipe, weight per ft. lbs	$12\frac{1}{2}$	17	22	33	42	60
Working pressure, lb. per sq. in	225	200	150	125	75	50
Delivery: At ft. distance	1320	1320	1320	1320	2640	5280
Delivery: Friction in lbs. for distance	6	5	5	4	7	17
Delivery: Gals. discharge per hour	1,200	3,000	6,000	15,000	30,000	60,000
$\frac{1}{4}$ and $\frac{1}{8}$ bends, lbs. each	——	50	60	115	200	275
Tees, lbs. each	——	80	100	200	300	400
Tees, with 4-in. outlet, lbs. each	——	——	——	154	250	300
Tees, with 6-in. outlet, lbs. each	——	——	——	——	266	315
Crosses, lbs. each	——	80	130	250	400	500
Crosses, with 4-in. outlet, lbs. each	——	——	——	190	296	370
Crosses, with 6-in. outlet, lbs. each	——	——	——	——	354	380
Lead, per joint, lbs	$2\frac{1}{2}$	4	$5\frac{1}{2}$	8	11	15
Hemp, per joint, lbs	$\frac{1}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	1
Gas main (not tarred) thickness, ins	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{1}{2}$
Gas main, weight per ft., lbs	9	$12\frac{1}{2}$	18	30	40	55

Note—The discharges given are based on the residual head from size to size, as though each smaller size was fed by the next larger. It is rare that a practical job would not be very much more concentrated than a string of mains so connected. One is certain to be on the safe side if the total head neutralized by friction, deducted as indicated leaves the required pressure at service points.

Street pipe is sold by the pound and it is customary, when estimating, to add the weight of one foot of pipe for each bell-end in the line and to take notice that 2-in. pipe is made in 9-ft. and other sizes in 12-ft. lengths. For high pressures, use as little hemp as will insure the lead not running through,—this will take probably 10 to 25 per cent. more lead per joint than stated in Table XXII.

Cast pipes of small diameter are capable of standing very high pressures so long as they are mere conduits, but when they serve as distributing pipes, the drilling for services weakens them materially, especially where tapering tinned ferrules are driven into smooth holes instead of tapping for threaded ferrules. Some engineers insist upon using the street gate valves and tapping with the pressure off instead of using machines that permit placing service pipes while the mains are under regular working pressure. The object of so employing the street main valves is to keep the valve system in working condition so there will be no delay from neglected valves when emergency demands prompt shutting off of the supply.

An infinite number of combinations of sizes and lengths of lines greatly varying the delivery per hour, are possible. The head or pressure available fixes the friction loss that may be sensibly undertaken. Installed as a village system, the sizes and lengths given in the table and working under the pressure stated for 10-in., would give excellent domestic service. Seldom or never, in any small system, would the sizes and lengths given constitute a continuous reducing line, but many other likely lay-outs would approximate the conditions that would be so imposed,—all tending to higher deliveries, than given, as the character of the layout departs from a simple continuous reducing line.

Dividing the friction loss given, by the hundreds of feet contained in the distance given under a size will give the friction loss per hundred feet for that size. For gallons delivered per minute, divide the hourly delivery by 60. The friction loss for 100 ft. and the delivery in gallons for one minute for the 10-in. given in the table would thus be 0.32 and 1000 respectively. For further data on friction losses, see Table XVIII.

CHAPTER XXXV

Laying Street and Other Mains

If a wrought line is being laid, an essential point is to have the threads *clean.* If the pipe is screwed up by hand power the heating of the ends will be slow and give time for conduction to expand the coupling so that when the joint is tight it is permanently so. If a traction engine, with universal chuck and arm, is employed to screw up the line the tendency is to do the work too fast,—the thinner wall of the pipe heats, at the thread, from friction, much faster than the extra metal in the coupling can be so warmed and the pipe tightens from expansion,—if so left it will be very loose when the joint is cold. When screwing up rapidly put a stream of oil over the thread, to carry away some of the heat, and hammer the coupling from all quarters with a light machinist's hammer, while the length is turning; when the length carries the screwed-up coupling around with it and then begins to turn in the coupling again, stop and wait two minutes and then give it a final whirl. For power turning, the line must be skidded up so the chuck can be applied; if one or two lengths are left free and aligned the chuck will take up any looseness, due to contraction of the pipe, as it screws up a new length.

For hand-work the pipe is usually entered in place in the trench and long handle wrenches with pull-ropes above the ground level are tugged by several men at each rope. Two wrenches with 4 men each—one in the trench and 3 on the tug rope—will handle 6 and 8-in. pipe. Wrought pipe mains are mostly used for high pressure gas lines.

In laying very large cast mains a trencher for excavating may be used in open ground. A traveling hoist, a locomotive crane, or its equivalent, usually rolling ahead of the trench, placing one length at a time, is necessary. If the pipe is 30-in. or larger yarning may be omitted; cold chunks of lead can be driven back at the bottom to even the lead space, fire clay bound to the joint crack inside the pipe and the whole joint space filled with melted lead. Sizes 12 to 24-in. may be swung into the ditch, one length at a time, with a crane or heavy tripod. Sizes less than 12-in. may be handled in strings of two to five lengths, according to size. The lengths are lined up on skids on the bank on the clean side; yarned and calked; then swung over the ditch, lowered and entered by the aid of tripods made and set as shown in Fig. 116. This plan allows turning the string on the bank when calking; permits inspection by sighting through on the bank and reduces possible obstructions to "running through" on the bell-hole joints and will keep a bigger force of trenchers, fillers and pipe men at work, and clean up the road-

way faster and closer than digging a bell-hole for every joint and "slinging" in one length at a time by main strength.

There is nothing special about the tripods shown. A village blacksmith can make the stirrups and bolts for the top and the straps to

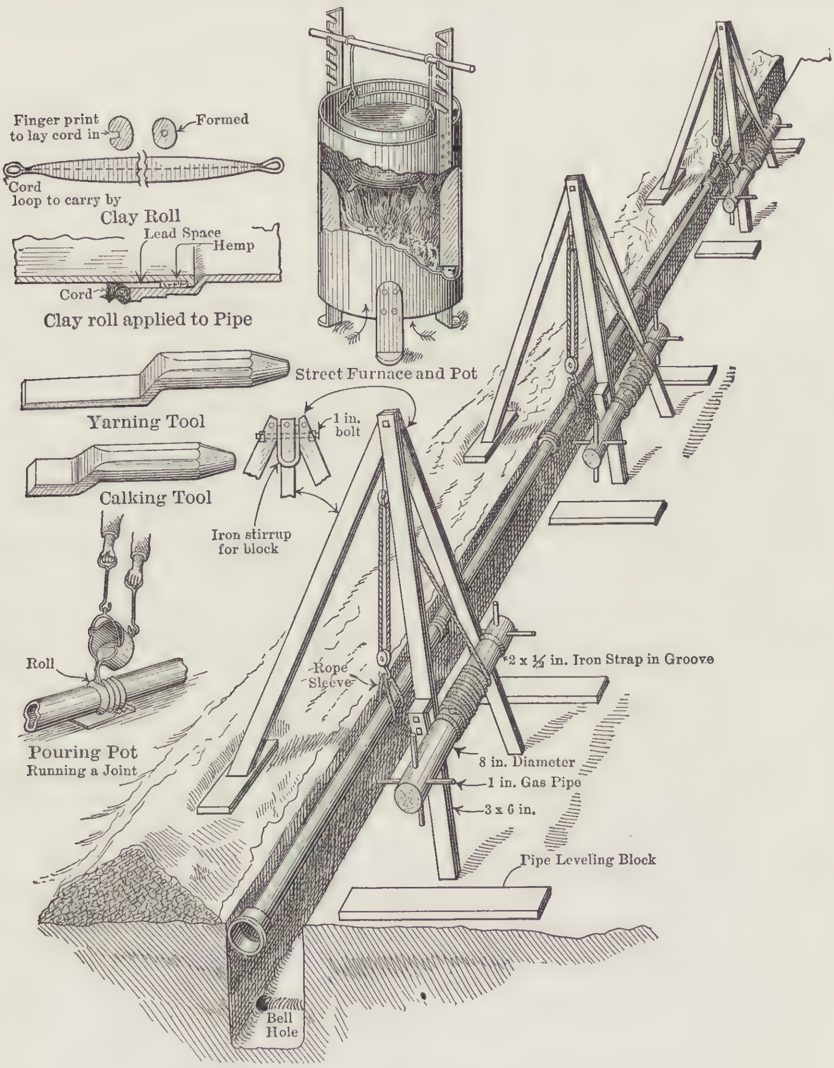


FIG. 116 JOB-MADE TRIPODS FOR STREET MAIN WORK

hold the windlasses; the turning arms are gas pipe driven through augur holes; the blocks and rope are ordinary; the sleeves for attaching the pipe to the lower blocks are scraps of rope spliced into rings,—chains may be used instead; the timber can be had at any yard and a carpenter's skill is not necessary.

The tools needed for laying the pipe are shown by separate sketches in Fig. 116. The furnace is an ordinary plasterer's salamander with racks riveted to the sides to hold up a big melting pot. The pouring pot has a looped handle, and a tilting loop in the side,—two hooks are used with it as shown and enough lead is carried to run the entire joint at one pouring. The yarning and calking tools shown are heavy—one yarning tool will do for any size but the face of the calking tool should suit the width of lead space; the yarn (hemp) is twisted tight and driven in hard; the lead cannot be calked hard enough to split the hub, and must be driven up solid.

For holding the lead in while pouring there is nothing better than a roll of well kneaded stiff blue or fire clay formed over a carrying cord as shown. The flat of the roll is applied to the space and the edges pinched up tight to the pipe and hub as shown. If the pipe is larger than 6 in. it is a good idea to tie a ribbon around the pipe on the roll in a way to hold the bottom in place without interfering with the pouring mouth. For pressures up to 40 lb. the sketch shows the division of the lead and yarn space; for higher pressures less yarn should be used.

CHAPTER XXXVI

Hydraulic Ram Service

There are two devices which utilize the power of the elements to lift water for plumbing purposes without the use of fuel,—the water ram and the wind-mill. There are many situations where a ram can be used to the advantage of the patron, but the chance is frequently ignored for lack of data at the command of the plumber who is not inclined to undertake something that may end in dissatisfaction and the loss of his customer's confidence.

A ram, as shown in Fig. 118, is a device that uses the force of a water fall to lift and store for service part of the water supplied to it. The water is led to the ram through what is called the "drive" pipe. The amount of water that can be stored is governed by the height of fall, the head of water discharged against, and the amount of water available to work with. The ram has no moving parts except the clack of a check valve opening to the discharge pipe and the plunger of the waste valve. The large air-chamber is to absorb the shock when the waste valve closes and to aid in getting the largest possible amount of water past the check into the discharge pipe at each impulse. The waste valve plunger is weighted down (open) to suit the fall. When a ram is put into commission, the water flows through the drive pipe (**C**) and wastes out through the open valve, as shown in Fig. 118. If the waste valve is properly weighted, its weight fails to resist the up-thrust of the water passing around its disc and snaps shut when the greatest velocity attainable under the fall used is reached in the drive pipe. The momentum of the drive pipe water then holds it closed for a time and forces the check valve open so water can flow into the discharge pipe (**D**) until the force is diminished sufficiently to permit the waste valve to fall open again; this action is repeated indefinitely.

In practice the ratio of lift to fall varies much, but to get the best results the lift and fall, and the length and size of drive to fall used should bear definite relations. It is obvious that a drive too large for the waste valve would not permit the water in the drive to attain proper velocity to accomplish good work; that a drive too small might accomplish no work at all, and that a drive too long would retard the velocity by presenting too much frictional surface. Also that a lift pipe may be too long or high for a given fall to overcome its head and friction and so end in no water being delivered to the point desired.

When the pipe sizes and length are right for the ram and fall employed and the lift and fall are proportional, the percentage of water

delivered is 8 to 9; that is, one gallon is stored at the proportional height for every 11 or 12 gallons sprayed out through the waste valve.

In the Table XXIII are given the size and length of drive, size of discharge, proportional lift and fall and an approximate number of gallons lifted and wasted for falls varying from 3 to 14 ft. Wherever the ratio of fall to lift increases or decreases the ratio of water lifted to

Table XXIII. Rams—Proportional Lift and Fall and Average Waste and Delivery

Feet Fall	Drive Pipe		Discharge		Gals. per Hour	
	Size, in.	Foot Length	Size, in.	Foot Lift	Lifted	Wasted
3	$\frac{3}{4}$	30	$\frac{3}{4}$	20	12	150
4	1	40	$\frac{3}{4}$	30	15	180
5	$1\frac{1}{4}$	50	1	40	25	300
7	2	60	$1\frac{1}{4}$	50	40	500
10	3	80	$1\frac{1}{2}$	80	140	1500
14	4	100	2	100	225	2500
*A	*C		*D	*B		

* For identification, see reference letters in Fig. 118.

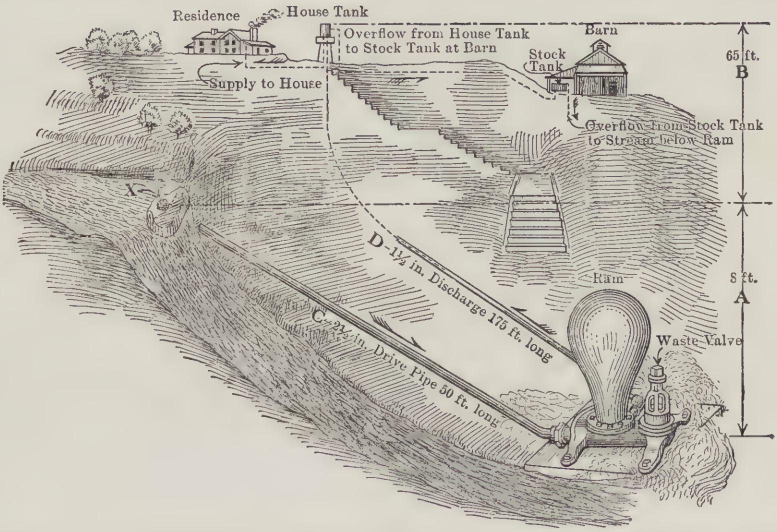


Fig. 118. Hydraulic Ram Outfit Delivering 75 Gallons per Hour, with Drive Pipe Supply of 1000 Gallons per Hour

that wasted varies accordingly. Water "wasted" is not literally wasted; it is the motive power by which the work is accomplished.

The friction in very long discharge pipes is equivalent to an increase of vertical lift,—see Table XVIII.

The frictional head for the drive pipes given does not exceed 10 per cent. of the fall head at the highest velocity attained in the drive pipe.

The minimum fall for a ram is about 3 ft. Any ram may work on 3 ft. fall if the volume of drive water is ample.

A small ram will work under any fall given.

Do not make drive pipes less than 50 ft. long for any fall under five feet if the fall for the size given in the table calls for 50 or more feet of drive pipe. A drive pipe may be coiled to get the required length between the ram and the water fall if there is no chance to set the ram the full distance away for a straight drive.

In Fig. 118, the ram is shown to take water at **X**, through a strainer which prevents sticks and drift from entering the drive pipe. The discharge is to an outside elevated tank. As the ram pumps without intermission, the overflow pipe from the tank is piped to a stock tank at the barn. The stock tank in turn overflows to the stream, but if there were chicken pens or pasture to be watered it could first be piped to them before wasting to the stream.

A ram should be well anchored; the drive and discharge should be protected from cattle, traffic and frost,—the latter especially with reference to the discharge. In cold climates it is best to set the ram in shelter so that frost will not interfere with its action in winter. There are different types of rams,—some that utilize the power of a stream to pump cistern, well or spring water, much as "water lifters" do.

Water-Lifters

There are several "water-lifters" in the market that do admirable work in the way of using city water pressure or private elevated tank or other water pressure to lift part of its power supply, cistern or other water to higher levels. These devices are simply water pumps automatically operated by water. The power and lifting cylinders are proportioned to the work to be done. The power water is seldom wasted. The most usual service is to lift city water to an attic tank for use on upper floors that the city pressure will not reach and to lift cistern water to a storage tank through the available power of the city pressure. This is accomplished by the regular city supply for sinks, closets and other fixtures being made to pass through the power cylinder, the filling of which at alternate ends pulls the sucker rod of the pumping cylinder back and forth and thus pumps part of the city water to a higher level than it will alone reach; or, if desired, puts it under a higher closed tank pressure than that of the city supply itself, or, lifts and stores an entirely different supply, as required. The pumping goes on without attention when water is drawn for any purpose from fixtures on the discharge of the power supply. If the power supply is unfit for domestic use or baths, the supply to closets, sprinkling water, etc., is passed through the power cylinder in order to pump or "lift" the desired amount of a suitable supply for those particular uses. If necessary the power water may be wasted in order to pump an ample supply of other water. These lifters are not more than 2 ft. long, look like a steam

pump, are cheap, and may be had from stock adapted to almost any conditions. The makers supply illustrations showing adaption to every possible service and give full data as to what can be accomplished under various conditions.

Air Engines

Hot air pumping engines have been so long in the market and are so very well known and understood that it is not essential to enter a tedious description here. The makers have elaborately described the construction and operation of these engines in a book which they will send on request.

Wind Mills

The use of wind mills are restricted for four reasons: The wear and tear is excessive when the wind blows over 30 miles per hour, and they are for this reason constructed to automatically "get out" of the wind at velocities ranging from 30 to 40 miles; in localities where the average wind velocity is very low it does not pay to worry with them,—7 to 8 miles average is as low as it pays to use the wind; if the wind does not blow, no work is done, and generally speaking the wind is spasmodic; on account of the calms when no water is pumped a larger storage capacity is needed to tide over idle mill periods than is needed where the power can be applied at will.

The pump used with a wind-mill must be self-priming,—always ready to work without attention at whatever rate the wind happens to run the mill.

It is scarcely worth while to put up a mill with a wheel less than 10 ft. diameter. For estimating the pumping power of mills and the proper size of pumps it may be taken that: Under a 15-mile wind a 10-ft. wheel will lift about 10 gal. of water 25 ft. per minute, and about half that much at a 50-ft. lift,—about $\frac{1}{10}$ h.p. "Lift" means the vertical distance from the level of the source to the point of delivery, in the tank. Under the same wind velocity (15 miles) a 12-ft. wheel will lift 50 ft. about 15 gals.; a 14-ft. wheel, 20 gal.; a 16-ft. wheel, 30 gal., and a 20-ft. wheel, 60 gal. per minute. The average for the larger sizes of wheels gives by doubling the wind velocity of 15 miles, about twice the power; at 8 miles per hour the work averages from a $\frac{1}{4}$ to $\frac{1}{3}$ that at 15 miles velocity.

Roughly, doubling the diameter of a wheel reduces the number of revolutions about $\frac{1}{2}$ and the average 10-ft. wheel will revolve about 60 times per minute under a velocity of 15 miles per hour. Makers' catalogues give much reliable data relative to their particular mills.

CHAPTER XXXVII

Hand and Power Pump Installation

A plumber should be well enough posted to suggest and execute work in lines allied to plumbing. Even those engaged in city practice will find it profitable to be able to handle the problems of both design and installation on sundry work in isolated districts too far away from the center of supplies and mechanics for the customer to find the various lines represented near his home.

Where power is used for pumping in out-of-the-way places it must be remembered that considerable delay will result from power failure and that repairs on such are very expensive. The work should therefore be done with reliable goods, and every effort made to provide permanent service. Some features that contribute to economical durable service in a pumping outfit are: a cylinder of small diameter to lessen the strain on the rod; a large lift pipe to reduce the velocity and friction of discharge from the cylinder; a long stroke pump to offset the small size of cylinder; the cylinder set below the permanent water level so it will always be primed; a large air chamber on the discharge (in addition to the chamber supplied by the maker); ample positive drain pipes to all portions that may freeze; automatic drainage if such can possibly be arranged; heavy clacks in the pump valves so they will close promptly; 2 to 4 cup-leathers, according to depth of working cylinder, so leathers will not have to be renewed often; a ready means of withdrawing all valves for repairs, without disturbing cylinder, lift pipe or standard; a good strainer with twice as much mesh surface as is needed when it is new and clean,—not less than 60 sq. in. of No. 60 gauze for each square inch of area of suction, in ordinary work; a means of operating *the* pump, or a pump by hand in case the power fails, and a means of pumping or delivering water at the standard in case the storage facilities are out of order. All of these points are embraced in the outfit illustrated in Fig. 120.

It is here assumed that the plumber begins where the well driller's work ends,—anticipating deep drilling to reach a supply, a drilling outfit was first employed to drill the hole and line it and that the casing stopped at the top of the ground. Like many other jobs in the author's experience, the earth in the case in mind was shallow,—but 15 ft. deep—and a good stream found at a depth of less than 40 ft.

The pump standard shown is a heavy deep-well pattern that can be detached from the power by removing a cotter pin from the pitman connection to the handle fork. It has a large air chamber with faucet

spout, 10-in. handle stroke, 14-in. countershaft stroke, rocking fulcrum, revolving bearer and, a frost-proof base, which diminishes the thickness of ice forming inside during severe weather and also keeps the water cooler in summer by shielding the lift pipe from the floor slab to the flange connection.

The power feature consists of a 2-h.p. gasoline engine belted to a countershaft with tight and loose pulleys, (engine not shown). The initial engine ignition is accomplished by four dry cells working through an induction coil. These are used only to start the engine. A switch is then thrown which cuts out the cells and switches in a small dynamo operated by a friction pulley running against the speed wheel of the engine. A reliable spark is thus obtained without depending on the cells which by regular use would soon be exhausted.

With reference to gasoline engines it may be said that there is much to be learned by the average mechanic, though common use of such motors in boats and vehicles in addition to their extensive commercial service has greatly familiarized all classes with internal combustion engines either through operation, care of, or repair work. The fuel, its compression, ignition, expansion and exhaust are subject to the same laws in all forms of gasoline engines. The Otto cycle (4-cycle) engine is almost altogether used in stationary and vehicle engines. In it there is normally one power stroke in every two revolutions. During stroke one of the cycle, the fuel is drawn in mixed with air, passing over and taking up the gasoline in what is called a carburetor, on its way to the cylinder. During stroke, two, the fuel is compressed into 20 to 30 per cent. of the original volume,—the resulting pressure being commonly taken as 60 lb. This pressure develops according to Boyle's law, but is greater in practice than is due to mere compression, for in addition to the temperature increase due to compression there is soon much heat added to the fuel from the cylinder walls; this heat expands the fuel mixture and so raises the pressure materially before ignition takes place: After compression, an electric spark ignites the mixture in the cylinder and it burns more or less instantaneously, according to composition. The burning gases, if there was no loss of heat to the cylinder and jacket water would probably reach 5000 deg. F. In practice it is necessary to cool the cylinder; this is usually done by circulating water around it, not only to keep the parts in working condition but to prevent the heat in the cylinder from raising the fuel to a self-firing temperature before the compression stroke is completed. The actual temperature of the burning gases in a water cooled cylinder is 1800 to 2000 deg. F. The expansion due to this almost instant and great rise in temperature as quickly raises the pressure to correspond,—equivalent to reducing the original fuel volume to $\frac{1}{10}$ or less. The power is applied

principally at the time of the explosion of the gases but is continued with decreasing force, as the gases expand, throughout the third stroke of the cycle. The fourth stroke is occupied in expelling the burned gases from the cylinder, preparatory to repeating the cycle. On account of the periodic application of the power it is necessary to employ a heavy speed wheel, the momentum of which absorbs the shock of the explosion and distributes the force throughout the cycle. In vehicle engines, the supply of gasoline is manually governed; that is the richness of the fuel mixture is varied by hand, within limits, to suit the power needed, and the operator is thus the governor. In stationary engines the intake valves and carburetor are adjusted to give the most powerful explosion, and a governor controls the admission of fuel to suit the load, giving the engine fuel for a power stroke only when it is needed to keep up its accustomed speed under the load applied.

Aside from these remarks, catalogues should suffice to enable one to select an engine for pumping service. Usually, the heaviest, and most expensive to a prudent buyer, for a given (claimed) horse power, is the best and cheapest engine in the long run.

The pump cylinder of the outfit is 26 in. long, brass lined; the suction and lift line in which it is used is $2\frac{1}{2}$ in. "plugged and reamed." "Plugged and reamed" pipe is merely card-weight pipe through which an iron mandrel has been passed to round it up; the ends reamed and the interior carefully inspected, the object being to insure the buyer that pump valves of $\frac{1}{8}$ in. or less smaller diameter will pass through the pipe freely. It is guaranteed to be cylindrical and free of interior hindrances, but as these precautions are taken before shipment, care must be taken not only in cutting and fitting this pipe, but also to actually slide the valves through each piece before placing it, in order to be certain that neither fitting nor shipment has flattened the pipe at any point.

The valves have bronze balls and four cup leathers. The sucker and bottom check may be placed or removed without disturbing any feature of the outfit beyond loosening three hook-bolt nuts and removing the bearer top. Four cup-leathers will work about three times as long as a single leather.

Having the cylinder no larger than the lift and the stroke as long as practicable reduces the power required to pump to a minimum, delivers more water than a large cylinder with short stroke and small lift pipe, and where power is used, operates at less fuel cost and with far less wear and tear on the parts.

Where the valves are removable with the rod, one man with a wrench can renew the cup-leathers, and examine the bottom check, too, if necessary, in one hour, while some other arrangements require three men with blocks and fall, as the whole standard, lift pipe, cylinder,

suction and rod have to be pulled up bodily and taken apart to renew a single leather that will last three to six months, according to the conditions it is working under.

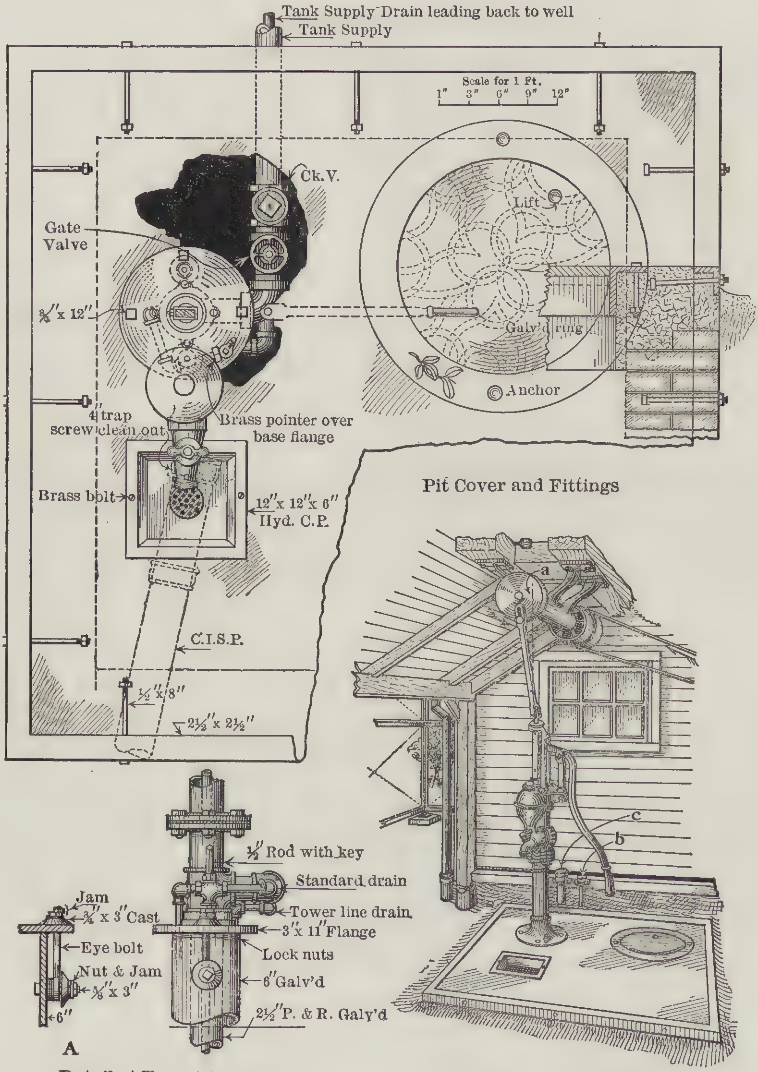


FIG. 120. INSTALLATION OF A HAND AND POWER PUMP OUTFIT

Four-cup valves are regularly made for $\frac{3}{8}$-in. iron pipe connection, but are often fitted with wood rod, especially when the well is deep, in order to relieve the pumper of all the weight possible. In a shallow well a little extra weight in the rod can do no harm, and as $\frac{1}{2}$-in. pipe is

much stiffer than $\frac{3}{8}$-in. and furnishes more wearing surface in the couplings and pipe and does not occupy as much room as the minimum size of hardwood rod, $\frac{1}{2}$-in. galvanized pipe is used on small power pumps between the valves and stuffing box rod. The change from the $\frac{3}{8}$-in. valve threads and rod threads to $\frac{1}{2}$-in. pipe thread is best made by increasing with a reducing coupling at the transition coupling on the end of the stuffing box rod and at the bale of the cylinder valve.

Valves operated by any ordinary rod, even of so short a length as needed for a shallow well, do not often give good service with double-action pumps because the rod is thus under compression on one working stroke, and to furnish a rod stiff enough make it either too large or too heavy. A single-acting pump puts all the actual work on the up-stroke and the rod is thereby always under tension on the working stroke, and unless the stuffing box is very tight a long metal (solid) or pipe rod will travel downward of its own weight.

An important point in setting a countershaft for a single acting pump is that the well center-line should cross the disc on the lifting side, midway between the center of the shaft and the center of the wrist when the wrist is set at half stroke (at the same level as the shaft). In this position the angular travel of the pitman is divided, the wrist crosses the well center-line twice on the up stroke, and the horizontal travel of the wrist is minimum and bisected by the well center-line, all of which will be made apparent by observing the center-line at the counter-shaft in the sketch and imagining an up stroke ($\frac{1}{2}$-revolution) to take place. For a double-acting pump the well center-line should cross the *center* of the disc shaft.

The concrete slab upon which the standard rests, is shown in the upper part of the sketch. Under it is a pit 6 ft. square, $3\frac{1}{2}$ ft. deep and walled with brick, layed in cement mortar. A length of soil pipe with tee receiving the waste of the cesspool shown, and a brass trap-screw ferrule clean-out in the pit, was built in as the wall was layed and the soil pipe connected to a waste water line. The cesspool is anchored by two brass bolts imbedded in the concrete. Access to the pit is through a 30-in. manhole ring with cover, the ring being anchored into the slab by laying the concrete with the bolts hanging in place.

The usual braces furnished with heavy pump standards need not be used when the standard is well anchored to a heavy slab. The pump base can be held firmly to the slab by four $\frac{3}{4}\times 12$-in. bolts with $\frac{3}{4}\times 3$-in cast iron washers over the nuts in the pit. The bolts should be suspended in place when the material for the slab is thrown in.

As a rule no attention is paid to formula to determine how thin the slab may be. The more important point is to have the slab heavy enough to sit firm under the lifting force when the pump is on the up

stroke. The author's rule for any power outfit with cylinder of 3-in. or less diameter, is to have the pump and slab weigh 3500 to 4000 lb. The quality of the bulk producer used in the slab concrete is not very important. Cinders or broken brick will answer. Portland cement should be used. The slab should be iron bound. The slab shown is framed with a $2\frac{1}{2}$-in. angle iron held in place by twelve $\frac{1}{2}\times 8$-in. bolts placed before the concrete was filled in. The corners of the frame are solid, a piece being cut out of the upper web and scarfed and welded with the vertical web or leaf bent to a right angle. The slab is about 12 in. thick and is made up—except an inch or so of rich stuff well troweled at the top—of broken rock, fragments of brick, cinders, and sand,—materials that can be found on almost any premises. The proportions of the mixture were about one of cement and two of sand to 3 parts of whatever else was being mixed. Some old pipe, any size from $1\frac{1}{4}$-in. down, cut into 5-ft. pieces and layed in two directions at right angles after 2-in. of the concrete has been placed will answer for reinforcing. A false bottom of scrap plank held up by 2×4-in. legs placed loosely under cross sleepers, so that the whole can be easily knocked down and taken out through the man-hole ring after the slab is set is the best means of holding up the mixture until it is stable enough to hold itself. Three or four days should elapse before the wood support is entirely taken out, though, it may be necessary to saw out the man-hole space immediately in order to work in the pit. The plan view of the slab shows the angle iron frame with anchor bolts, pump base, cesspool and manhole. The inside line of the brick wall is dotted, and a section of the man-hole and slab is sketched at the right, on a line through center of man-hole ring. The slab is broken to show the pipe connections in the pit.

The gate valve makes it possible to shut off the line to the elevated tank when necessary. It may also be used to furnish full hand-pumping pressure at the faucet-spout, at times. The check valve retains in the tank line whatever the pump delivers and prevents the tank-line water from following the sucker on the down stroke in case the lower pump valve should not seat perfectly,—it is also a safe-guard against drawing tank water at the pump faucet and insures that one can only get water fresh from the well, at the pump. A supplementary air chamber made of 3-in. pipe was placed on the 2-in. tank line. It and a stop and waste box which drains the tank delivery line back into the well casing are indicated by **c** and **b** in the general view. In severe weather the waste stop box can be opened and the line emptied quickly after the engine is stopped. The pump stock and connection is drained to below the frost line by a separate drain taken from between the lift pipe and gate valve and piped back into the well casing. This drain is fitted with a

socket-head cock with square rod extended up through the pump base. Over the pump base is a common check and guide pointer. It points to a guide word "on" or "off" stamped in the metal. The connection is of $\frac{1}{2}$-in. pipe,—sufficient size for strength and durability. The rapidity of drainage regulated by a thumb cock, which can be opened enough to empty the stock quickly in cold weather or turned partly off and left permanently open,—as desired.

The $2\frac{1}{2}$-in. well line is made up of a 36-in. drive well point screwed into the lower end of cylinder, and the lift pipe built up from the cylinder to the top of the casing. In a shallow well, the whole can be lowered into place as one piece. A $2\frac{1}{2}\times 2$-in. tee above the top of the casing is usually made the beginning of the tank delivery on outside pump work instead of taking it from the top of the air chamber of the standard, as is often done with inside pumps.

If it be necessary to lock a lift pipe to the casing it can be done as illustrated by the sketches at the lower left corner in Fig. 120. For this it is necessary to cut off the casing 8-in. or so above the bottom of the pit. The cutting can be done in a short time with a diamond point,—taking one cut around with an obtuse point, and then recutting with a point ground to a smaller angle. The cut end of the casing is hammered down square and level. Two holes are bored in the casing, on opposite sides, 6 in. from the top. A 3x11-in. (for $2\frac{1}{2}$-in. well pipe) steam pipe flange is bored for the two drain pipes mentioned and for two bolts to hold eye-bolts in place, as shown. The well pipe is lock-nutted to the flange by means of a long-screw and two nuts, the screw projecting above the upper lock-nut sufficient to attach the connection. The flange is then secured to the casing by the eye-bolts through which pass other bolts inserted through the holes drilled in the casing, all about as shown by the front view general elevation sketch and by the view detail sketch, **A**, at the left in Fig. 120.

CHAPTER XXXVIII

Drive Well Equipment

Wells are made by excavating and walling in earth or rock; by boring with earth augers; by punching with a slitted spring cylinder on the order of a post-hole digger and lifting the material by the spring of the cylinder; by the dropping of a heavy drill attached to a rope lifted and lowered by a walking beam; by rotating a hollow drill studded on the cutting edge with black diamonds; by twisting and sand pumping a pipe down, and by literally driving the pipe. All of these methods are good in certain cases, depending upon the size of the well, its depth and the character of the material.

In earth, a plumber can bore or punch a well; his dry-well auger will do the boring and a post-hole digger with a rope attached to the handle will pierce any ordinary depth if the strata clings or can be made to by throwing clay into the hole. He can twist down a casing, large enough to work a sand pump in, without tools other than he can make in the shop and he can drive tubular wells up to $2\frac{1}{2}$-in. without expensive equipment.

If rock is to be drilled it is best to employ a man well prepared for it.

More "driving" falls to the lot of the plumber than any other sort of well work. For temporary supplies, seepage water may be had in many places at depths shallow enough to place the cylinder at or near the surface. For such wells, $1\frac{1}{4}$ or $1\frac{1}{2}$ in. pipe with a well point on the lower end may be driven down with a rail maker's beetle.

For a permanent domestic drive well supply the ideal water comes from gravel and bolder beds inclosed between two impervious strata that preserve the supply and keep it from being contaminated by immediate seepage water that may be polluted through sinking within the limits of cesspool or barn yard dissemination or, at least be mixed with water that has percolated through such polluting strata. It is evident that the best conditions for the plumber are not to be found everywhere, for character of the strata, and proper synclines must both figure in trapping the supply into a suitable basin.

If one has not had experience or time to inquire as to conditions, or to study the lay of the ground over a considerable section, he would do well to employ the neighborhood water-witch, not that witch-craft is more than a cloak to hide common knowledge, but because the man posing as a water-witch has studied the situation in his locality, thereby knows the drift of the underground water, etc., and chooses to keep the knowledge well in hand.

Assuming the plumber has knowledge of the premises and that a well for permanent use is to be driven, the question is how.

To drain the stock and pipe to below frost and provide openings for underground lines a pit should be made under the pump top; the pit is the first step. The pump standard should have a frost base, rocking fulcrum, stuffing box, cock nozzle and big air chamber and be tapped for not less than 2-in. pipe. The well line should be made up of a gauze covered point, brass-lined cylinder, 2-in. plugged and reamed pipe, and extra heavy couplings, as shown in Fig. 122. The sucker should have four cup-leathers and ball, spool, or rubber-faced poppet valve. The bottom check should have a rubber packer, and a valve to match the sucker valve. The whole should be arranged to place or withdraw all the valves through the standard by removing the bearer top. A $\frac{3}{8}$ or $\frac{1}{2}$-in. galvanized pipe rod will answer better than a wood or solid rod.

Cut the pipe into lengths to suit the driving arrangement; shrink a coupling on each piece; drill straight down 15 or 20 ft. with a plumber's dirt drill; make up the lower end of the line and stand it in the drill hole. *Driving* is next in order: If there is no sort of apparatus at hand for driving, nail up a guide and weight of wood like shown in the sketch, using a pulley or well-wheel at top and a rope to lift the weight. Use a common pipe cap to drive on. Have good long threads on the pipe and screw them up tight so the hammering will not break the joints. Be careful to not mash the pipe or the valves will not pass through. All pipe ends must be reamed. If the driving is hard, pour water into the line. When the "hard-pan" is reached it may take 50 licks to drive the pipe an inch. The hard-pan will vary from 2 to 6 ft. or more thick and also varies in hardness. The water lies just below the hard-pan and may rise 10 or 20 ft. in the well pipe when reached. When the driving begins to go fast, it shows that the point is through the hard-pan. At this time begin to keep account of the depth driven thereafter so as to be sure to get the whole point below the hard-pan and to stop driving while a coupling is wedged into the hard-pan material. This is to prevent seepage water from leaking down into the purer supply and to keep the pure water from wasting up into the seepage water. In order to insure the waters not mixing, it is best to use a short piece pipe and a heavier coupling (larger than the head of the point) below the cylinder. The heavy coupling is thus certain to be jambed in the hard-pan. The point should be driven no further than necessary,—it might enter or pierce the *second* hard-pan.

If there is enough of such work to make it worth while, a tripod like shown in Fig. 122, with stirrup and bolt at the top should be made to drive with. Whether a single or double pulley is used depends

upon the weight. A 200-lb. weight requires a double sheave pulley at the top and a single at the bottom. There is no better way than manual labor to operate the weight for ordinary drive well work. Two men can easily work a 150 or 200-lb. weight,—one man can work a 100-lb. weight.

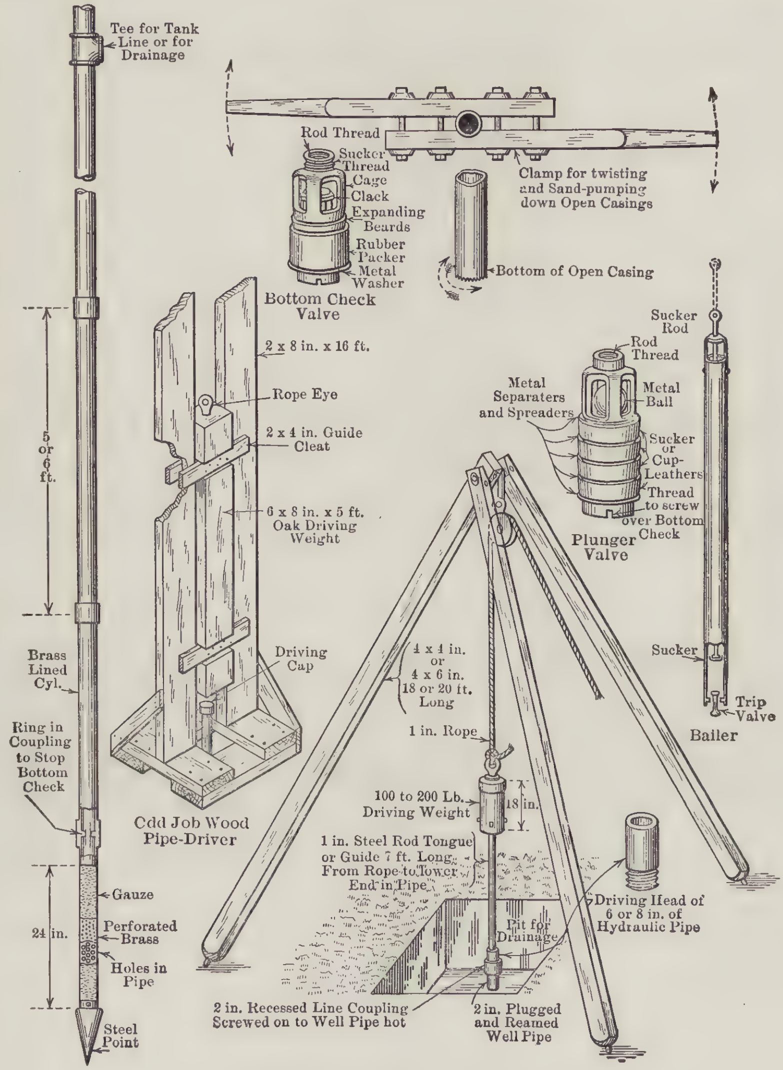


Fig. 122. Well Driving Equipment

The weight can be made up of a 1-in. steel rod 8 ft. long, with eye for the rope or pulley, and a piece of 4 or 5-in. steam pipe and cap anchored to it as shown. The pipe is filled with lead to within 2 in. of the driving end and finished out with babbit metal. The filling is anchored in the

pipe and the rod held centered by set screws run into threaded holes in the pipe as shown. For a driving head, a piece of hydraulic pipe is used,—the guide rod of the driving weight fitting the hole loosely, the pipe head acts as guide for the falling weight.

If a large casing is to be twisted down, two wood handles are bound to the pipe with bolts as shown. To begin with the first length of pipe is stood in a bored hole, and twisted back and forth, as shown by the arrows in the sketch. When the first length is down, another is added. Pour water in the pipe to make it sink fast if the filling is being removed as the pipe is sunk; notching the bottom end of the first joint helps the pipe to cut its way down. The material within is removed with a sand pump made like shown in the sketch. Water is poured in to soften the material and the sand pump is lowered to it with a rope,—by the bale if the sucker is too stiff to fall. Pulling the pump up by the sucker rod draws the muck into the barrel of the pump. Setting the pump down on end trips the bottom valve and empties the barrel. If the material does not come up fast enough churn it with a rod or bit attached to a rope. The emptying of the casing may be left until the pipe is well down if desired. A plain end pipe or casing requires lowering into it a complete well line like shown; or, a point and cylinder with a packer can be lowered and the packer expanded to make tight with the casing at the proper depth. By this plan the casing can be used as a *lift* pipe.

If an open end strainer is used on the end of the casing, the lower end can be closed with a bag of plaster of Paris. When wetted the plaster expands in setting and closes the bore of the pipe thoroughly. A cylinder with packer can then be set above the strainer as above mentioned. The open end strainer makes the better job. One should study the catalogues of the goods he uses in this line of work for there is much valuable knowledge in them.

CHAPTER XXXIX

Yard Hydrants and Street Washers

Hydrants and hose boxes being stationary outdoor fixtures, have frost proof valves are arranged for repairing without digging up the body. The hose box or "street washer" is primarily for hose use but answers for domestic service by using a short piece of hose or a pipe goose-neck with hose end. Stiff goose-necks cause yokes to get broken and are therefore little used. A hose box head favors unusual strain on the connecting pipe when the earth freezes, and the supply for it must be more carefully provided with swings than for a hydrant. The hydrant nozzle stands above the ground level so water can be drawn

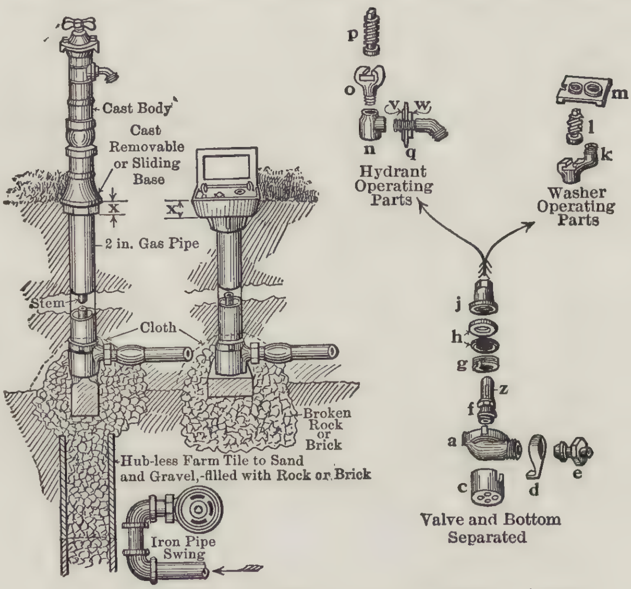


FIG. 125. STREET WASHER AND YARD HYDRANT WORK

directly into vessels. The nozzle is threaded for hose. These fixtures are shown in Fig. 125. The valve is the same in both; the body is of 2-in. gas pipe; the stem $\frac{1}{2}$-in. plain or galvanized water pipe; the valves, bottoms, yoke and nozzle are brass and the box head and hydrant top, cast iron.

The operating parts are: for the hydrant,—**g**, **h**, **j**, **n**, **o**, **p**, **q**, **v**, **w**; for the box, **g**, **h**, **j**, **k**, **l**, **m**. The stationary bottom and valve parts for both are: **a**, **c**, **d**, **e** and **f**. These are seen in the small side sketches. **a** is the bottom casting; **c**, sand cup; **d**, sand cup keeper; **e**, pipe coupling,

f, stationary valve seat spud; **z**, is the waste water slot; **g**, waste washer keeper; **h**, waste washers; **j**, valve body, containing pressure washer and water ways, at either side of the washer; **h**, fits into recess in **j**, and are held in place by **g**; **k**, is the box yoke holding foot of brass lead screw **l**; **l** and **p** have coarse triple thread to make the stem travel fast; **m** is the box plate,—it fits over yoke and has thread for screw **l**. The plate is held in the head by a lug, keeper and bolt. The hydrant **a** has thread for **p** and is bolted to top casting; **o**, is the fork; **n**, stem; **t**, $\frac{3}{8}\times\frac{1}{2}\times\frac{3}{8}$-in. tee; **v**, ribbed slide to cover nozzle slot; **w**, lock-nut and **q**, brass or malleable nozzle.

The waste slot, **z** extends above and below the waste washers when valve is closed, so water in the stem will run out; when the valve is open the waste washers are above the slot or ditch **z**, to prevent wasting at the bottom.

The paving level is shown by **xx**. A good form of iron pipe swing connection is drawn in plan view below the hose box. The swing permits frost to lift the body more or less without breaking the pipe connection. Care should be taken not to cover the swing with rock when placing the waste water filling. A brick or rock bridge over the swing, covered with a cloth, adds to the chances of the connection not breaking under frost action.

A hose box is not opened so frequently as a hydrant and is generally opened wide. For this reason, a dry well is not essential for the waste water. Some broken rock or brick, covered with a cloth should be placed as shown. The amount of rock needed must be judged by the character of the earth,—the more impervious the strata, the larger should be the pod of filling.

Yard hydrants are opened so often, and so frequently by children who do not open the valve wide enough to close the waste hole, that a dry well is essential, especially so if the hydrant is near a cellar not water-proof. If the well water does not settle, the ground and hydrant body will fill, so that frost puts the hydrant out of service. When the body contains water to the ground level, the stem is also full and freezing is certain to call for stem repairs if nothing more.

A dry well should reach coarse sand or sand and gravel. It may be lined or not, according to circumstances. The lined well is best. The cloth used over the filling should be old carpet,—a rug or scrap of carpet or tarpaulin is best.

Where the temperature falls to zero, or lower, hydrants and hose box stocks should extend 3 to 5 ft. in the ground.

Sill hose boxes are similar to the ground box, but lighter. Self closing hydrants are made, but they are not well suited to high pressure.

They are, however, good water savers and mitigate the trouble with waste water.

There is much to be learned in judging what ails leaking hydrants. Dripping at the nozzle may indicate a short stem, a chip under the washer, or a washer too thin, or a bent stem. Water flowing steadily but slowly from the ground may be caused by a leaking pipe, a loose collar, or a loose, twisted or damaged pressure washer. Water flowing from the ground when the hydrant is in use may be caused by loose waste washers or a split stem. Water flowing out of the body when the hydrant is in use may be from a split stem or loose waste washers and generally points to a choked sand cup. One should make sure as to the location of the trouble before going to the expense of digging out a hydrant.

CHAPTER XL

Air Chambers

No formula has been devised for air chambers, that the plumber can apply with satisfaction; none, in fact that will help him much more than a rule of thumb based on practical experience.

The author's rule is to place pipe air chambers at all faucets; to locate them so they will receive the direct thrust of the water; to have the chambers at least 12 diameters long when the pressure ranges from 20 to 40 lb., and not less than 18 diameters long, where possible, when the pressure exceeds 40 lb. per sq. in.; to use faucets that close slowly on high pressure, and to place chambers at other points, on high pressure lines, where reaction is likely to be checked with good effect. If these hints are followed there will be little or no trouble from water-hammer, provided the service lines are of ample size.

A big chamber on the incoming main service has a good general effect in that it absorbs the follow-up thrust of the water in the main service up to that point, but it has very little effect on the reaction in branch lines inside the main chamber, for it cannot govern the velocity of the water in the branches occasioned by drawing at the faucets.

A feature of many jobs that promotes water-hammer trouble is that the branch lines are too small. A $\frac{1}{2}$-in. or $\frac{5}{8}$-in. faucet on a $\frac{1}{2}$-in. line gives a water-way too nearly the same size as the bore of the pipe, and consequently the velocity of the water in the pipe during drawing approximates that at the point of issuance, thus setting up conditions for maximum reaction. The larger the pipe and the smaller the faucet water-way, the less will be the force of reaction, for reaction is equal to the action, and the action (velocity $\times$ weight) being governed by the size of the water-way, it is reduced in proportion as the area of the pipe cross-section to the area of the faucet water-way increases.

Water is perfectly elastic and though it will assume the shape of any cavity confirming it, it is practically nearly incompressible. The force required to stop it when in motion is about the same as would be necessary to check a solid of the same weight and velocity. As with a solid, the quicker its motion is checked the more violent is the reaction and effect. When closing a faucet the momentum of velocity must be overcome, a force greater in proportion to the velocity, than that of the mere static pressure of the supply. Closing a faucet slowly has the same effect as an air chamber but any faucet that can be closed quickly is certain to be so used, for that is the object of quick-acting mechanism.

An air chamber simply provides a means of checking the motion of the water slowly regardless of the action of the faucet.

The absence of water-hammer because of an adequate air-chamber merely shows that the thrust of the water is well cushioned,—the reaction is there, none the less, and is absorbed by the spring of the air. The force of the moving water compresses the air in the chamber until the force of compression (greater than the static pressure) equals that of the moving water. The water is thus brought to a standstill. The excess of air pressure in the chamber then overcomes the supply pressure and forces the water back in the pipe until the chamber pressure has dropped below the water pressure; the water pressure again compresses the air to above static pressure, but with a decreased force amounting to about $\frac{1}{3}$ of the first thrust, and so on until the water is in repose.

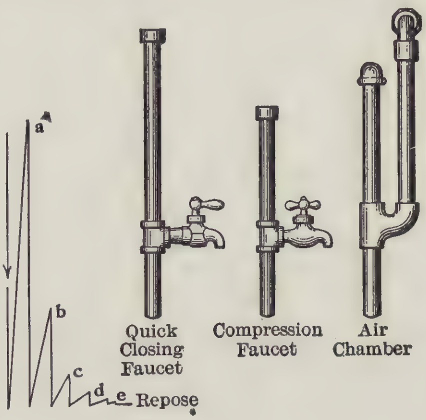


Fig. 127. Air Chambers

A rough graphic illustration of the first rebounds of water-hammer is shown in Fig. 127 by the line **a b c d e.** The first five strokes constitute almost the whole of reaction at any pressure. The stopping of the water and the stroke from the first rebound produce the principal effect when there is no cushion. The whole reaction following the first rebound seems to amount to only about half of the force of the first rebound.

As shown in Fig. 127, smaller chambers may be used with slow closing faucets than with quick action, but chambers should always be provided for quick action when the pressure is high, so that quick-action faucets may be substituted later, if desired.

A chamber may be of larger pipe than the supply, if available height necessitates it. Very large chambers are sometimes used as accumulators where short periods of quick-drawing beyond the regular capacity of the supply is esse tial, and also where the supply is poor or fails at times. In the latter cases a check valve is used below the faucet.

There are effective mechanical devices in the market to take the place of air chambers, but because of the expense, and other reasons they have never been very much used.

CHAPTER XLI

Service Water Accumulators

Heavy drawing at some particular point from a small service may be easily provided by installing a 30-gal. or larger kitchen boiler accumulator as shown by the solid lines in Fig. 129. If the pressure is moderate only, there should be at least one fixture above the accumulator, as indicated by the dotted line, so the pressure will not have to compress the air in the accumulator. Also, there should be an air inlet valve above, so the water will flow freely when the accumulator water is needed. If it is essential that water always be had at a moments notice for the special service, a check valve should be placed in the service below the accumulator.

If the service pipe is simply too small for the duty or is incrusted so it does not answer under the available pressure, or the pressure is poor at certain hours, the difficulty is best overcome, supposing no larger service is possible, by first piping the water direct to the highest point as indicated by a dotted line in the sketch. It will then flow over the loop between drawings and thus keep the accumulator and the old service full.

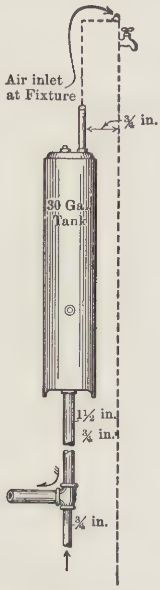


FIG. 129. ACCUMULATOR IN DEFICIENT SERVICE

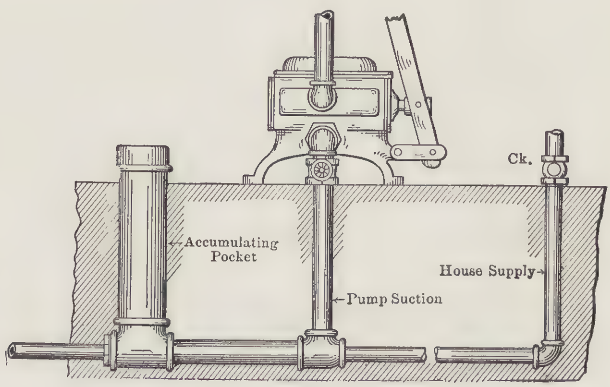


FIG. 130. PUMP POCKET ON HOUSE SERVICE

Pump Pockets

Pump pockets are really simple air tight accumulators that answer the same purpose as above mentioned, the special service being the supplying of the pump that fills the attic tank. The pump, even

though for hand power has a suction capacity on the active stroke exceeding the ordinary house service on very low pressures.

A single acting pump leaves half of the time for water to flow into a pocket; during the other half the pump may take all the water the service will flow, together with that accumulated during the non-pumping stroke. It is obvious that a large air chamber placed in the service near the pump and connected to the pump by a full size suction will allow the pump to draw more water than it is possible to get otherwise. Such an air chamber (pump pocket) and connection are shown in Fig. 130. Between pumping strokes the air chamber fills to some extent; during pumping strokes, the suction draws on the water accumulated in the air chamber for any deficiency that may occur and the compressed air in the chamber helps to deliver the water. This arrangement being inserted in the house service, the pump would, if allowed, interfere with the house service more or less at times,—possibly by drawing water from the kitchen tank, rocking ball-cock levers in water closet tanks, etc. To free the house service of these possible interferences a check valve is placed in the service as shown in the sketch.

CHAPTER XLII

Water Heating, Steam, Fire Coils, Water Backs, etc.

When figuring out the size of steam or fire coils, power of water backs, grate surface for water heaters, size of storage tanks, etc., it is well to remember that while the rules following are a more or less definite basis to work by, no hair-splitting exactness is necessary for the reason that good personal judgment will always be a great factor in fixing the value of several elements and that probable errors of assumption in the premises for figuring, will therefore overshadow any gain hoped to be obtained by very close figuring.

A single adverse feature of practice, or false note in estimating may be a small matter, and often the plus and minus errors affect the various factors of a problem in a way to neutralize each other and thus produce in practice a close approximate to the result figured for. But, the bulk of the errors is just as likely to trend one way, so, when estimating, foresight cannot be too keen in ferreting out and providing for the actual conditions that *will* prevail in operating the job, if the practical result is expected to come anywhere near agreeing with the theoretical deduction.

The object of figuring is to find what will get the desired result. If the provisions for the job are too liberal in the estimate, the job is lost because some other fellow figures closer to the requirements; if inadequate equipment is figured on, and the job thereby obtained, it will not satisfy the demand, and money is lost in altering the work.

Some of the points that prohibit using a single definite rule for all cases are:

The coating of galvanized pipe varies in thickness; the processes of making brass pipe may cause variation in its conductivity; the shape of a coil, and kind of fittings, generally discounted, may affect the result; the kind of water being heated has to do with the average efficiency of coil surface,—the whole heating surface, of whatever type, will usually become more or less incrusted with one material or another and thereby alter the rate of conduction to far below its efficiency when new; the comparative stillness of the contents of a storage tank permits matter in suspension to settle upon the upper surface of the coil; comparative stagnation of water heated by submerged coils, prevents the coil surface from doing its utmost; coal may vary; the attendance be poor or the draft bad.

A point of contention in connection with submerged steam-coil heating is whether the mean of extremes generally accepted as the

temperature of the water acted on by the coil, should be discounted to agree with a mean assumed to be actual for the job. The usual course of reckoning, is, for instance: steam at 3 lb.,—222 F., incoming water 40 deg. F., water delivered from storage tank, 150 deg. F., mean temperature of the water coil works in, 95 deg. F. Now, while all the incoming water must be raised, say from 40 deg. F., the heat is not imparted at a temperature difference of 127 deg. F., as the mean of initial and terminal temperatures imply. The assumed conditions exist only when the tank is heated up without drawing from it. When the job is in regular service, the tank is hot; incoming water cools the mass proportionally, possibly never to less than 100 deg. F.,—considering this the case, then: $100+150=250$; $250 \div 2=125$; the real prevailing mean of the water in the tank. $222—125=97$ deg.,—the real temperature difference.

This does not affect the amount of heat necessary to warm the water, but the rate of transmission. If considered at all the difference between the actual working mean assumed to prevail as against the accepted mean of initial and terminal temperatures is the factor to allow for. A deduction of 1 lb. per hour, per square foot of coil surface, from the pounds of steam regularly assumed to be condensed per hour per square foot of coil is made by some estimators to cover the supposed disadvantage of transmission against the assumed actual mean and temperature difference.

In practice, the water circulates over the coil surface more when it gets warm than when it is cold, and the rate of transmission is increased. How nearly this increase comes to offsetting the effect of the above noted decrease in temperature difference is problematical but the author is not in favor of making any allowance for it. The total consumption of the day in many jobs is practically drawn at some three or four intervals aggregating a fraction of the time so small as to tax, at those times, the capacity of the service line supplying the outgo from the storage tank. In these, the initial conditions are closely approximated during drawing, and from one interval of drawing to the next the coil is practically working on the basis given by the mean of initial and terminal temperatures.

Considering all of these indefinite elements, and the many other uncertainties of general practice it will be seen that there is much that must depend upon the factor of experience, and that a liberal allowance of surface for untoward circumstances is generally in order.

Efficiency of Water Backs and Fronts

In order to determine the power of a new water back and connections under the most favorable circumstances a test was made by the

author, as follows: With an 80-gal. tank heated by a large clean cast water-back containing $1\frac{1}{3}$ sq. ft. of surface exposed to the fire and gases, and with a clean, hot, loose fire of good coal, allowing open live fire to the bottom edge of the back, it appeared by firing it for one hour, that about 38500 heat units per square foot per hour had been added to the water. About 10 lbs. of coal were used with something like 35 per cent. efficiency. These conditions were not normal: the draft was strong; the fire condition exceptional; the combustion more brisk than ordinary; the per cent. of live fire adjacent to the back, unusually large; the water back clean (some sort of incrustation would soon take place and greatly reduce the transfer of heat), and *larger* than ordinary.

In common practice, ashes and clinkers bank against much of the surface; the fire temperature is lower; the back ordinarily much smaller than the above and the per cent. of "dead" surface therefore always larger. Considering all these points and noting the service of many average jobs, it was found that the average absorption for common domestic use ranged from $\frac{1}{4}$ to $\frac{1}{3}$ the amount above mentioned, according to kind of water, age of back and connection, size of back, position of back, amount of cooking and washing done, etc.

For a working rule for backs, fronts and coils, it was found that allowing 12000 heat units per square feet per hour passed muster without bringing in any complaints, and that figure has been adhered to for stove and range work. This seems to be ridiculously poor service, but it should be remembered that the range fire-box is designed primarily to bake with and that the water heater is a secondary feature, seldom given the choice position, in an arrangement that is poorly adapted to such service at best.

A 30-gal. kitchen storage tank, the smallest size ordinarily used, holds about 250 lb. of water. One square foot of range fire-box surface, more than the average box contains, assuming that it takes up 12000 B.t.u. per hour, will raise the temperature of 30 gals. of water only 48 deg., say, 40 deg. to 88 deg. or, 60 deg. to 108 deg. F.

The average bath room requires about 6000 B.t.u. per hour to warm it to 70 during zero weather, when the adjoining rooms are kept at 70 deg. F. The foregoing shows how futile is the attempt to warm a bath room by a coil heated by the range box in conjunction with the ordinary domestic hot water service. There are cases, of course, where the result is not bad,—in mild climates, or where the fire-box surface is extraordinary, or where furnace heater help is available, but as a rule bath room coils connected to range backs are not worth the annoyance, to say nothing of the expense of installing.

CHAPTER XLIII

Range Boiler Connection

Kitchen storage tanks for hot water are generally called "boilers" though there is neither boiling in the tank nor in the water heater in the fire-box. They are made for use in both vertical and horizontal positions. The vertical type is almost altogether used, and though the holes for pipe are not located for horizontal use it is often pressed into service in a sidewise position on account of low head room or cramped floor space. They are made of both copper and galvanized iron or steel. Comparatively few copper tanks are used. Copper is soft and the tank often so thin that a spiral reinforcing rib is needed within, to strengthen it. In competition work the omission of the rib has led to a ripping of the sheet, or an utter collapse from the boiler syphoning when the water was turned off. A copper boiler flattened by accidental syphon will sometimes round up again under the water pressure without apparent damage. If the city pressure does not inflate it, a force pump will.

Galvanized boilers are made in two weights,—standard and extra-heavy, the latter for high and the former for low pressure or competitive work. These boilers are so cheap that it does not pay to try to repair the light weight. The stock is too thin to tap well, the skin of galvanizing cannot be soldered tight and the work of getting down to the iron is too expensive, considering that a new break may soon develop. Only the guaranteed full capacity brands will hold the number of gallons branded on them; the cheap makes fall at least 10 per cent. short. It pays to use the heavy weight for all pressures. A galvanized wrought iron shell may last 15 years or more; steel shells serve 6 to 10 years. These periods are for carefully made goods,—if there happens to be blisters on the interior—spots where the galvanizing did not "take"—the boiler may fail from interior pitting in from two to four years. Interior pitting is the usual cause of failure regardless of the length of service. Boilers are dipped in the galvanizing vat before the bottom head is put in; this coats the seams and rivets. The bottom end is again dipped after the head is placed. In some makes the seams and rivets are brazed on the interior before the galvanizing is done.

A family range should have a storage tank of from 40 to 60 gals. capacity, according to number of fixtures and size of family; boarding house and inn ranges having from 1 to 1½ sq. ft. surface in the fire-box heater need from 60 to 120 gals. storage capacity. Many cottage ranges are fitted with 30 gal. tanks; these are inadequate on wash days if the

heating surface of the range box is sufficient. If a "front," side box, or coil is so small as not to overheat the water in a 30-gal. tank during *baking* hours, the whole arrangement is too small to countenance in good work.

If two ordinary heaters for simultaneous use are connected to one tank, the connections should be $\frac{3}{4}$-in. from heaters to the point of junction and 1-in. from the junction to the tank. If an inn has an 18 or 24 ft. 3 or 4 section range and a water-back is used in each fire-box, all connected to one large tank, the tank should be ordered special and the holes tapped not less than $1\frac{1}{2}$-in. for four boxes with $\frac{3}{4}$-in. fire-box holes; the manifolds connecting the backs to the tank should be $\frac{3}{4}$-in. for the most remote heater, 1 in. for the next, $1\frac{1}{4}$-in. for the next and $1\frac{1}{2}$-in. from the nearest heater to the tank. If the fire-box holes are tapped 1-in. then the manifolds, beginning at the remote section should be, 1-in.; then $1\frac{1}{2}$-in. then 2-in. for the two backs nearest the tank. The manifolds or main runs of a multiple connection must be, at any point, able to easily carry the full capacity fed or received at that particular point. The above sizes are based on the aggregate areas taken care of at the various points.

Stop cocks should not be placed in range connections. If one box of a multiple connection is not being fired, let it stand idle but filled,—this will do no harm, but the misuse of cocks may cause an explosion. If a plumber must use cocks on a double connection, so one back or stove may be disturbed without interfering with the service of the other, let them be lock-cocks not "key-locked" but pad-locked.

For domestic use, the supply to a storage tank should be entered at the top, so turning off the water will not empty the tank, and extended to near the bottom so the cold water will not be turned loose in the mass of hot water. The cold should enter the hole that keeps the delivery pipe most remote from the side range hole. The delivery must have a hole near the top to prevent the contents of the boiler from syphoning when the house pipes are drained. Cold water issues from the syphon hole, marked **S** in the sketches of Fig. 135, so it should be turned toward the shell. The syphon hole ought to be lined with brass so corrosion will not enlarge it; the hole should never be filed in,—drill it. $\frac{3}{32}$ is large enough for a plain hole.

The upper hole of a water-heater must be at the top of the cavity to avoid forming a streaming space that will not fill with water, and which would cause rumbling; connections that are choked or too small also cause rumbling.

In Fig. 135, are shown a number of typical range connections. The waved arrows indicate a good position for furnace heater or coil connections. The schedule given on the sketch is a key to the purpose of each pipe shown.

Sketch **A** is the most usual type of connection. For city service, the sediment pipe is often connected to a waste pipe; in country jobs the

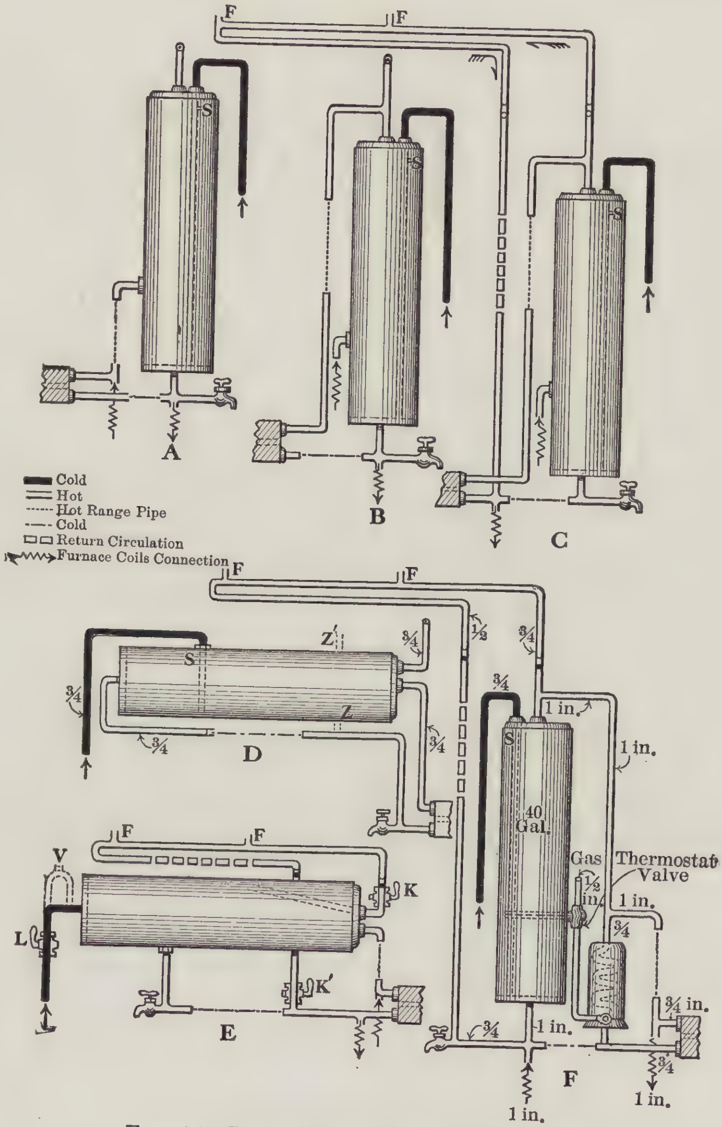


FIG. 135. COMMON RANGE BOILER CONNECTIONS

faucet is more often used and there is also usually a means at the top for filling the tank with a bucket and funnel.

The style of connection shown in sketch **B** gives good service and delivers hot water to the fixtures in a shorter time than is possible when

the upper stove connection enters the side hole. It is more used since lead pipe house lines are rare.

Sketch **C** shows a return circulation loop; **FF** are fixture branches. The principles of **B** and **C** are otherwise the same.

Sketch **D** shows a vertical boiler connected horizontal, as done by a man with no idea of what is necessary to get proper results. The lower half of the contents are "dead" and there is no way to drain the tank; it will rumble from steam when very hot; cannot be completely filled and the warm water zone is very limited. A horizontal boiler with the holes better located would supply the lower range connection from point **Z**, and the hot service would be taken from **Z′**.

Sketch **E** is the same boiler or tank shown in **D**, with the side hole turned down. A return loop has been added; **K** and **K′** cocks must be turned to stop the water to hot faucets; the tank can be drained; the range connections are passably well located, but the difficulties of supply and outgo cannot be entirely overcome. For the delivery, a stop-cock might be used at **L** for convenience, but the boiler would empty down to the middle when the house drain cock was turned. To avoid this a loop like dotted in might be formed in the supply, and a relief valve, piped to the sink, used at **V**. The hot service commands most of the hot water in the tank, but very careful work is necessary to cutting and fitting the "pitched" thread for the hot water outlet.

A complete set of connections for a vertical tank are indicated in sketch **F**. The only feature in it, not shown in some one of the other sketches is the gas heater and its thermostatic valve. There are many forms of these heaters in the market, each consisting of an insulated case covering a copper coil or other heating surface placed over Bunsen burners. These heaters may be used without thermostats, but the trouble of turning the gas up and down by hand is very troublesome and unsatisfactory. The thermostat stem expands and contracts in length with the rise and fall of the temperature of the water in the tank. The stem carries the gas valve disc and opens or closes the gas way automatically so as to keep the tank water at the desired temperature. The valve by-passes enough gas to supply a pilot light.

Some forms of large gas heaters are used without a tank, the gas burners being capable of heating the supply required as fast as it will pass through the pipe. This style, being a general heater for the whole job, is placed in the basement. The gas is controlled by a differential valve,—opening a hot faucet lowers the water pressure between the faucet and the differential valve at the heater through which the supply passes; the stem is then forced along, through a stuffing box, and operates the gas valve stem. The draw-backs of this form of service are that no return circulation is provided; dead cold water must be drawn before

hot water reaches the faucet; water is heated that is not used and there is no point of stagnation to allow sediment to settle out of the water as there is when a tank is used. The storage tank form of this class of heaters overcomes all the troubles mentioned above.

One point that must be watched with all forms of automatic heaters is that a faucet left open accidentally will run up an enormous gas bill.

When estimating the cost of gas fuel for water heating, 900 B.t.u. for natural gas and 650 B.t.u. for ordinary lighting and fuel gas may be allowed per cubic foot. Of this it may be assumed that not over 80 per cent. will be transmitted to the water.

Many water supplies contain salts that are set free by heat and thus give trouble by filling or incrusting the range box and connections. Market water softening devices are used to prevent these formations. In some cases an extra box is kept on hand ready to be inserted. When the incrusted box is removed a solvent for whatever the filling may be is used to clean the box and it is then kept ready for re-inserting.

Trouble from water back incrustation, can be avoided by heating the incrusting supply by conduction,—using rain water in the back and circulating it through an elevated tank, much as car heating is accomplished. The conduction heater for warming the hard domestic supply is interposed in the soft water range connection. This plan is usually too expensive for ordinary installation.

CHAPTER XLIV

Double Boiler Jobs

"Double" boiler jobs afford one means of heating refractory supplies that incrust the fire-box heater, but the principal use of such has been to utilize one range heater for warming the hot domestic service of two separate pipe systems working under different pressures, each serving certain fixtures of the same job. The condition prompting this kind of service is generally a low street pressure that will not reach the upper floors of a city residence. For the upper floors it so becomes necessary to pump the water to an attic storage tank; the tank system of piping is under the higher pressure and is fitted to the inner one of the two boilers, partly to escape the chances of collapse of the inner boiler, partly because the upper floors may use less hot water, and also because the inner boiler depends for heat upon conduction from the water of the low pressure system surrounding it. But one range connection is made. It connects the outer boiler to the fire-box heater in the ordinary way. The range heater should be large,—in proportion to the work it had to do.

All the principal features of a double boiler system of the type where one boiler is placed within the other are shown in Fig. 137, in which the light double lines connected to the top of the boilers are hot service and the heavy black lines, cold service.

There are two other types of double boiler jobs. Both are fitted with separate boilers. In one, each is heated by a separate water-box,—sometimes by two water-heaters in one range fire-box. In the other, a single fire-box heater is used. It heats one boiler by direct circulation, as usual in ordinary work; the second boiler is heated by conduction, the conduction heater being interposed in the upper pipe of the range connection and the conduction surface device being connected to the boiler that will be called upon to supply the smaller amount of hot water.

All of these methods may be fitted so that either system may be used on the fixtures on the one or two floors not regularly supplied by the street pipe during the hours of heavy usage. This is done in the simplest way by connecting the supplies somewhat as shown in Fig. 137. In practice a single fork handle is arranged to turn two or four cocks at once,—the cocks being set so that the tank supply is turned *off* or *on* when the street supply, by the same action, is turned *on* or *off*. Automatic cut-offs serving the same purpose without personal attention, and operated by the change of pressure are to be had in the market.

Some usual features of the type of job illustrated are: The sediment pipe of the inner boiler is usually connected to the sediment pipe of the outer boiler "inside" of the cock emptying the outer boiler. In the case of copper tanks this may save collapse of the inner shell, which might occur should the inner boiler be emptied while the outer one is under pressure.

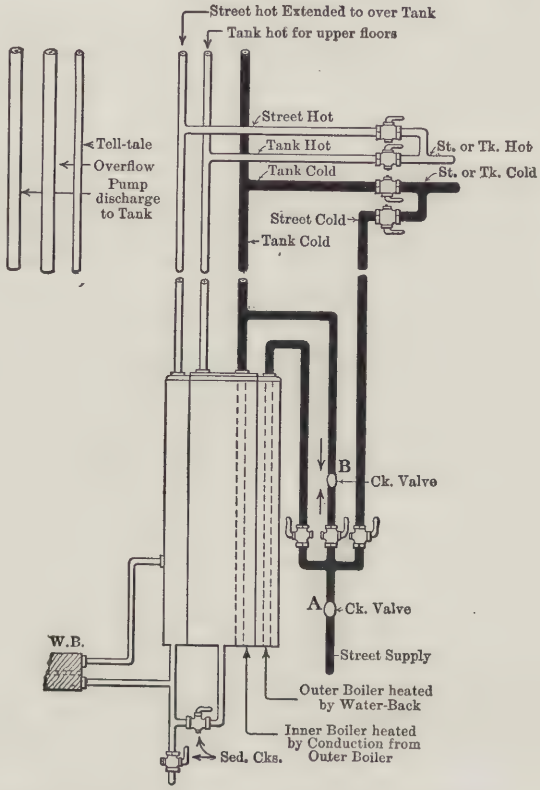


FIG. 137. PRINCIPLES OF DOUBLE BOILER WORK

Another safe guard is the provision for insuring the inner boiler keeping full by means of a check valve located at **B**. The higher tank pressure normally keeps valve **B** closed against the city pressure. Should the tank pressure fail, the city pressure opens the check **B** and thus automatically keeps the inner boiler filled until tank service is again established. The check valve **A** is to prevent the pump from drawing water back through the house service. No pipes are shown in Fig. 137, except those necessary to betray the principles of double boiler service. The attic tank may have all the features common to tank service. The pump may be any ordinary double or single acting hand pump, or a power pump operated by electric motor, hot air engine or gasoline engine.

CHAPTER XLV

Fire Coils in House Heaters

Domestic water heating coils in water and steam house heaters are much akin to and behave like range fire-box coils but give better returns per unit of surface. The author allows, for fire coils, 1 sq. ft. of coil surface for each 20000 B.t.u. required per hour. This allowance was arrived at as follows:

Wherever possible coils in shallow fire-boxes are placed in the fire line; if the location admits, the coil is fitted with a swing, as shown in Fig. 140, that will allow adding, at will, $\frac{1}{4}$ more surface than the minimum considered in proportioning the surface; the average fire temperature is taken to be 700 deg. F.; only half of the coil surface is taken to receive the "full" benefit of the fire; because of dead coals next the coil, ashes, clinkers, variation of fire from varying attendance, change of weather, etc., the average acting temperature of the fire is presumed to be 350 deg. F. on half of the surface; for the other half, the temperature of the heater wall, due to reflection and temperature of heater contents, is taken to be 180 deg. F.; conduction is supposed to diffuse the fire temperature and thus give to the whole coil surface a mean of the temperature on the front and back half of the coil pipes, 265, thus:—$350+180=530\div2=265$; the initial temperature of the water is taken to be 60; terminal temperature 140; mean temperature of coil water acted on, 105 deg. $265—105=160$, the temperature difference. The surface of the coil is assumed to transmit 125 B.t.u. per hour per degree difference. $160\times125=20000$. This, like the range box rating, appears to be a very poor showing but it is as much as can safely be counted upon, in a shallow fire pot carefully fired, considering all the elements that go to deteriorate fire coil service. Several coils based on these figures have gone through a number of ordinary winters without complaint, one winter in which the thermometer did not touch zero and one during which it fell from 10 to 22 below zero and hovered around zero for weeks.

In two-family houses separate coils and 52 gal. tanks were used; in three-family houses, a coil like shown in Fig. 140 was used with one 150-gal. tank. The demand for hot water was satisfied by firing to favor the coil or by banking the fire partially with ashes, according as found necessary. In very severe weather during which the capacity of the house heater was taxed and the domestic duty on the coil remained about the same, of course, the swing was used to reduce the active coil surface. In mild weather the swing surface was pushed in and the firing was done to favor the coils.

When it is suspected the coil will not receive due attention, it is better to use much larger tanks than above mentioned, say large enough to give the coil 3 to 6 hours work on a filling. In this way there is little danger of heating the water to steaming at any time and there is an accumulation of hot water for meals and bath times. Also, the coil has work to do in the intervals between heavy drawings and will do it with very little special attention to the fire.

In deep fire-pots the level of the good fire line varies; the heater is left to take care of itself for hours at a time between firings; a deep coil intended to catch the fire at different levels cannot be swung in or out and will do very little work at times, and overdo it at others. The top of the fuel may be black for a long time after firing. In the case of coke fuel there is never a caked cap of fuel to throw the heated gases out at the side against a coil. So, in deep fire boxes it is found better to place the coil in the combustion chamber over the fuel, or, in the smoke flues.

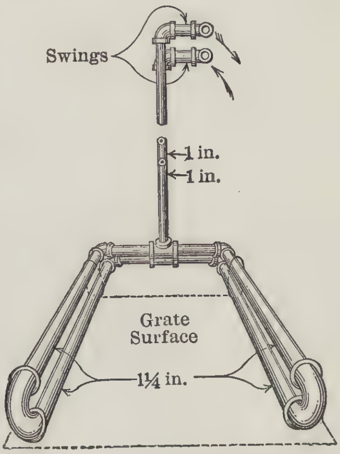


FIG. 140. COIL SURFACE ADJUSTABLE BY SWINGS

When a coil is placed in the combustion chamber, 12000 B.t.u. are presumed to be transmitted per square foot of coil per hour; when it is placed in the smoke flues of a heater, 10000 B.t.u. are allowed. These low ratings are used with a view to providing ample surface to take up heat rapidly during the periods when the fire burns in a way to favor the coil, and to get a reasonable service, through the liberal surface, when the fire does not favor the coil. With such, a large storage tank is necessary,—large enough to hold the aggregate of several hours average hourly consumption.

It is not worth the while to make any particular allowance of grate surface in a house heater for the domestic water heating coil for residences or two or three-family houses unless the heating apparatus is figured on a niggardly basis providing no margin for additions or rare cold snaps. When the heater capacity *is* figured close, the coil should be considered if the duty is heavy, but the very conditions that call for providing for it usually operate against the coil receiving even the slightest attention.

CHAPTER XLVI

Heating Water by Submerged Steam Coils

The coating on galvanized iron pipe has, through its zinc, been very generally supposed to retard the transmission of heat to the extent of making it inadvisable to employ it for steam heating coils in storage tanks, but, rather recent experiments have shown its transmission to closely approximate that of plain iron pipe. Iron and galvanized pipe may therefore be taken to have the same value for coil surfaces and, for equal surfaces to transmit about half as much heat as brass pipe.

The author's first efforts to establish a working rule for steam coil work were based on Prof. R. C. Carpenter's data for clean surfaces, to the effect that the transmission of heat from steam to water through iron pipe increases with the temperature difference about as follows: from 150 B.t.u. per square foot per hour per degree for 100 deg. difference, to 228 B.t.u. for 125 deg. temperature difference.

Ordinary conditions of practice fall within this range, as will be seen from the following assumed extremes and mean: Lowest probable incoming water temperature, 40 deg. F.; highest probable tank temperature, 180 deg.; low pressure steam temperature, (5-lb. gauge) 228 deg.; $40+180=220$ deg.; $220 \div 2=110$, the water mean; $228—110 =118$ deg., the temperature difference.

The rate of transmission for 100 deg. temperature difference is (as above) 150 B.t.u. per square foot per hour, per degree, and the rate of transmission for 125 deg. temperature difference 228 B.t.u. per square foot, per hour, per degree. Proportionally, 118 deg. difference would give about 164 B.t.u. per hour, per degree temperature difference for plain iron pipe and for galvanized pipe assumed to transmit heat at the same rate. This literal application of the data mentioned was tried out and failed,—the surface was entirely inadequate because no allowance had been made for the untoward conditions of actual practice. The assumed rate of transmission was repeatedly decreased to increase the surface, until but *125 B.t.u.* per square foot per hour per degree temperature difference was allowed for *brass pipe*, and the figuring is now always done on this, the brass pipe basis, and the surface so determined *doubled* if *plain* or *galvanized iron* is to be used.

Upon this basis, the outfit for hot water service for the job shown in Fig. 142 of Chapter XLVII, develops as follows: incoming water, 50 deg. F.; terminal temperature 150 deg.; mean temperature coil works on 100 deg.; steam for coil, 227 deg.: $227—100=127$, the temperature

difference. $127 \times 125 = 15875$ B.t.u. transmitted per hour per square foot of brass coil surface.

The fixtures to be served are in an office building and are: 150 lavatories using 20 gals. each per day, principally in the daytime; 25 slop sinks using 50 gals. each, per day, principally at night. It is necessary to consider only the call made by the lavatories. $150 \times 20 = 3000$ gals. of water used in say, 10 hours, or 300 gals. in one hour. $300 \times 8.3 = 2490$ lb. water to be heated through a rise of 100 deg., per hour. $2490 \times 100 = 249000$ deg. rise.

As 1 B.t.u. will heat 1 lb. of water 1 deg., this 249000 equals 249000 B.t.u. required per hour to heat the water used by the lavatories.

Expressed in horse power this is equal to about 7.5 B.h.p. Expressed in pounds of steam, taking 954 B.t.u. as the latent heat in one pound of steam, it means $249000 \div 954 = 261$ lb. of steam to be condensed per hour.

Expressed in square feet of submerged brass pipe surface necessary to transmit 249000 B.t.u. per hour, it means $249000 \div 15875 = 15.6$, say 16 sq. ft. of brass pipe coil surface, or in round numbers, 50 lin. ft. of 1-in. brass pipe, or 100 lin. ft. of 1-in. plain or galvanized iron pipe needed in the coil.

The 261 lb. of steam to be condensed, divided by the square feet of surface found needed in the coil shows that 1 sq. ft. of brass coil will, on this basis, condense between 16 and 17 lb. of steam per hour, and that iron pipe will condense between 8 and 9 lb. per hour.

The sizes of the steam pipe flow and return for the coil are marked on the sketch in Fig. 142, page 235. The trap should be large enough to easily drain 1000 sq. ft. of steam radiation.

The call for warm water is more uniform in office jobs than in apartment houses. Twice the average hourly consumption, or 600 gals. will therefore be ample for the tank, especially when the coil is under thermostatic control. For an apartment house job with the same average hourly consumption, a 900-gal. tank would be better.

The problem of required coil surface may be approached from a different point of view from that given, a method used by many in contract work, on filtered stream water. It gives values considerably higher than shown in the foregoing example.

The method is based on the following: The relative condensing power of submerged iron and brass pipe is something like 1 to 2, and within the range of water temperatures usual in practice, and with steam at ordinary pressure, the condensing power of iron and brass pipe may be stated in even tenths, 0.1 lb. for iron and 0.2 lb. for brass pipe, of steam condensed per hour, per square foot per degree difference between the steam and mean temperature of the water worked on.

0.1 lb. of low pressure steam is approximately equal to $960 \div 10 = 96$

B.t.u. transmission per degree difference per hour, or 9600 B.t.u. per hour for 100 deg. temperature difference. 0.2 lb. is therefore 192 B.t.u. per degree difference or 19200 per sq. ft. per hour for brass pipe, for 100 deg. temperature difference.

With the above *degree* constants the latent heat of steam taken at 960 B.t.u. per lb. may be used for any low pressure steam temperature in converting heat units required into pounds of steam to be condensed.

Having the pounds of steam to be condensed, however obtained, the process of finding the coil surface is: multiply the temperature difference by the constant, 0.1 or 0.2, according to the kind of pipe coil to be used, and divide the pounds of steam by the product so obtained. The result will be the required coil surface in square feet.

As an example: 74 gal. or 614 lb. of water per hour are required to be heated from an initial temperature of 40 deg. F. to 180 deg. F., by means of a steam coil of iron pipe placed in the storage tank and taking steam from a low-pressure main at, say 3-lb. pressure.

Three pounds gauge pressure corresponds to a temperature of 222 deg. F. Then, 180 deg., the ultimate temperature of the water, minus 40 deg., the initial temperature of the water, equals 140 deg., the required rise in temperature. Also, 40 plus 180 divided by 2 equals 110 deg., the mean temperature of water the coil will work on. Then 222 minus 110 equals 112 deg., the temperature difference between steam at 3-lb. pressure and the mean temperature of the water in the tank surrounding the coil.

Then, 112 multiplied by 0.1, the *degree constant* for iron pipe, equals 11.2 lbs. steam condensed per square foot of I.P. coil surface per hour. For a brass pipe coil it would be $112 \times 0.2 = 22.4$ lb. condensed per hour.

$614 \times 140 = 85960$ B.t.u. to be transmitted to the water per hour; $85{,}960 \div 960$, equals about 90 lbs. of steam to be condensed per hour.

The 90 lbs. of steam to be condensed, divided by the equivalent condensing power of one square foot of iron pipe surface, 11.2 lb., equals 8 plus, the number of square feet of I.P. coil surface required. If brass pipe be used, 4 sq. ft. of surface would be needed.

It is not usual to count the surface of fittings in water heating coils.

Any allowance that seems wise in view of the conditions for a particular job can be made, either in the method figured by or by an outright increase or decrease of the coil surface determined by figuring. The type of coil, relative storage to heating capacity, kind of building, whether there is automatic control or not, kind of water, etc., all affect the surface needed more or less in one way or another.

In instances where everything favors a minimum of coil surface, such as a very small tank, no control of the coil, and clean soft water, the most conservative person may be tempted to figure by the degree con-

stants in lieu of making an allowance from surface obtained by the first method.

Pro Rata of Grate Surface Allowed for Coils

To determine the pro rata of extra grate surface required in a house heater on account of the steam taken by a domestic water coil, allow, where the heater is large and a skilled fireman is to be employed, a fuel consumption of 8 lbs. per square foot of grate and an efficiency of 9000 B.t.u. per lb. of fuel; 1 sq. ft. of grate, extra, would do for the 85960 B.t.u. required per hour, as figured in the foregoing example.

If the heater is small and will likely be fired by the family or houseman, proceed as follows: Assume the fuel ordinary and the degree and skill of attention about such as may be expected from the average house-man. For this reason allow but 5 lbs. coal consumption per square foot of grate surface and count upon it developing but 8000 effective B.t.u. per pound, or 40000 B.t.u. per square foot of grate per hour. This will give margin enough for any case.

It is good practice to divide the total hot water consumption for 24 hours by 4 or 5 and thus get the delivery for 5 or 6-hour periods, and then make the storage capacity equal to the water consumption for the period. In this way the extra grate surface for the heater can be held down to that necessary to heat the average hourly consumption instead providing enough to meet the call of the heavy drawing hours.

CHAPTER XLVII

Hot Service Layouts and Provision for Pipe Expansion

It is very easy for a journeyman to see in his mind's eye a whole residence or store system almost as soon as he sees the building or its plans. The larger jobs are just as easy, only one should not try to grasp the details in their entirety at one sweep of the mental vision. A big job is really but a little job on a big scale. If such is to be planned, let the mind comprehend a suitable general scheme first, seeing in the mind only the main lines without regard to size of pipe or other details. Then consider the service with a view to sizes of mains, etc., weighing the structure, in the sense of character, shape, probable duty of the job, character of attendance and the associated structural elements and equipment features bearing on the service, so as to determine the general treatment. Then take up the details of lines and connections, one line at a time. In this way there will be no confusion in the mind, nothing is likely to be overlooked, the whole will be in keeping in the end and there is little unnecessary work done,—for, if there is anything wrong with the general plan it is most likely to so come to light and balk either the whole scheme or make necessary a departure from the typical line layout before much premature detail has been figured out.

In Fig. 142, is a sketch of the main lines and hot storage tank for a tank-fed hot water job, supposed to be the simplest possible layout for taking care of expansion and keeping hot water at the fixture branches. The building is assumed to be 20 lofts above ground. The pipe sizes marked are relative,—they may be less or greater according to the job. As given, they will work on the service indicated on the sketch. Any number of departures may be made from the treatment shown to suit a particular job.

Two variations are indicated by separate sketches, one in the way of expansion, shown at the left, and the other one at the right, showing a means of dividing the service between tank feed and city pressure feed.

For providing expansion, the highest water temperature was taken to be 180 deg. and the lowest temperature 50 deg. F. This gives a range of 130 deg. A corrected decimal gives 0.00008 in. as the linear expansion per foot per degree F. Multiplying the height by 8 and pointing off five places therefore gives the expansion for the whole height for 1 deg. temperature rise. The lines are 240 ft. high,—240×8 (as directed) $= 0.0192$ in. for 1 deg. The range of temperature is 130 deg.; $0.0192 \times 130 = 2.496$ in., the utmost expansion that will have to be taken care of.

No wood building is high enough to call for provision for expansion in plumbing service. A steel frame with pipe attached to it may be considered to approximately walk up and down with the pipe under

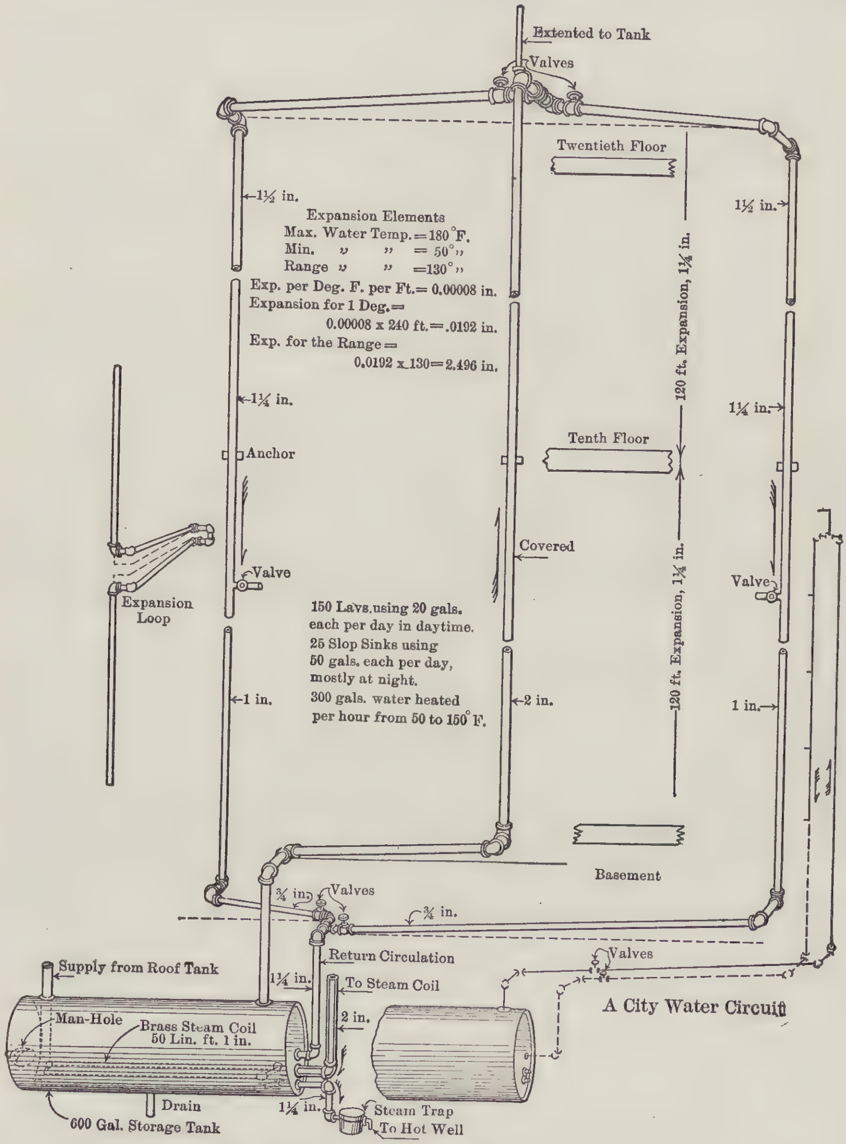


Fig. 142. Hot Water Service from Roof and Street Supplies

temperatures common to both frame and pipe. This would not be true of a frame structure.

The pipe may commonly be supposed to be fitted at 50 deg. If a whole line anchored in the middle could be strung with its temperature

30 deg. ahead of that of the supporting frame, the possible effect would be an increase of fitted "drain-pitch" below the anchor and a corresponding decrease, of no consequence, above it. If the "up" and "drop" lines were equally well covered the initial drain-pitches at top and bottom would be very closely maintained during service.

As the utmost expansion to be taken care of is covered by the range element as figured, the expansion element for any length provided in the swing or drain pitches will answer for short laterals so far as expansion is concerned. The more pitch the better. The expansion to be taken care of in branch connections varies with the distance from the anchor.

If a main line is anchored at top and bottom, and the expansion is taken care of by a loop near the center as shown by separate sketch at the left in Fig. 142, the top and bottom swings need only to take care of drainage, but the play of the loop should be fitted to take care of the line expansion without destroying the drainage grade in the laterals of the loop, even though the turn-out swing of the loop has to be anchored to divide the play.

It is the author's practice to leave uncovered that portion of the drop pipes which act merely as return circulation.

The reason for the small return connections is that usage contributes mostly to the work of keeping the water moving in the lines and circulation throughout is not therefore dependent upon a difference in temperature, nor does the relatively small return connection restrict the change of contents as it would in a heating job.

If desired, the drop lines may, at considerable more expense and the loss of individual control of each floor, be snaked into a loop for each toilet room, instead of making branch swing connections, with valves, as implied by the sketch. "Snaking" the lines makes it unnecessary to consider expansion,—the short distance between loops eats up the expansion and contraction elements without perceptible effect.

A relief pipe should be extended to the tank to free the line of air.

In some jobs, a separate flow is made for each toilet room or group of rooms or floor, according to the job. This multiplies the lines, shut off valves and drain valves, and calls for immense connecting headers, making altogether an imposing array of fittings quite bewildering to one used to simple jobs, and indicating what a plumber is capable of when the occasion presents itself. Such work is not alone a feature of late years plumbing, as may be witnessed in buildings 20 odd years old,—the Hotel Savoy of New York for instance.

In case the city supply is reliable for a certain number of floors, the hot service may be proportionally divided and two storage tanks provided with coils and other fittings somewhat as though the work was

for two separate jobs. This is suggested by the loop and tank indicated at the right in the sketch. Where the service is so divided, the "drops" of the tank system from the top of the city loops down should be fitted to act as return circulation only, for the tank system. The city service loops are provided with similar returns and preferably the fixtures on city service are also fed from the drop pipes. If desired, the top of the city loops may be cross-connected and valved so that in case of failure of a city main, the tank service may be supplied to the whole building. Likewise the tanks may be connected so as to carry both storage tanks on tank duty or otherwise as occasion may require.

CHAPTER XLVIII

Tank Heaters

For many apartments, house jobs, small pools, baptistrys, etc., separate coal water heaters are preferable. The heater may be a small affair of the type called tank heaters, or a regular house heating circulator, according to the amount of work to be done.

A tank heater with damper regulator is shown connected to a horizontal tank, in Fig. 144. **C**, is the cold delivery to tank and **H** the hot service, with return circulation indicated by the dotted arrow. The tank is partially supported by iron bands attached to overhead beams. Under the tank are two 2-in. pipe stanchions to the floor. They are fixed to the bands by bolting through the 2-in. pipe caps.

The tank also has a steam coil for winter use. If high pressure steam is used throughout the year no tank heater is needed except as a precautionary measure: The coil steam is controlled by a thermostat. Though not essential it is better to use a thermostat. There are many forms of thermostatic regulators. Maker's catalogues describe them in detail.

Whether steam is used at high or low pressure it is best to return the condensation to the steam boiler by gravity, if possible. For low pressure jobs it must be so returned, and the coil in the tank is required to be above the boiler water-line enough to more than equal the differential of water level due to loss of pressure between the boiler and the most remote point of usage. The difference in level is usually small between the tank and boiler, but it is not this alone that must be allowed for,—it is the maximum difference of level in the whole heating job that must be considered. In a good steam job of ordinary size not traversing over 150 ft., 6-in. difference in water levels may be ample. In scrimpy jobs, two feet may be necessary. If other contractors are doing the steam heating the plumber should inquire about the loss of pressure before locating his tank. When steam is used through a reducing pressure valve it is generally expedient to trap the condensation to the general receiver where it can be pumped back to the boiler through the boiler feed pump.

When the tank in a job like Fig. 144 is large enough it should have a man-hole, located to suit the job, and, a hand-hole in the end, through which to place the coil pipes. When the tank is small, the hand-hole alone will answer, but it makes the work of piping and cleansing very awkward. The coil ends are brought through small holes and usually lock-nutted tight. The coil should be low so as to keep it working in

the coldest water in the tank to promote local circulation of the whole contents and to increase the volume of the hot water zone, etc. The location and size of all openings should be specified to suit the job, when the tank is ordered.

In figuring out an ordinary outfit of the kind shown, first estimate the number of gallons of hot water that will be required per hour; the temperature of the incoming water and the highest temperature it is expected to raise the water to. Then allow 5 to 8 lb. of fuel per square foot of grate per hour, according to the size of the job and the skill of attendance. If the fuel is good count upon 8000 B.t.u. per pound for

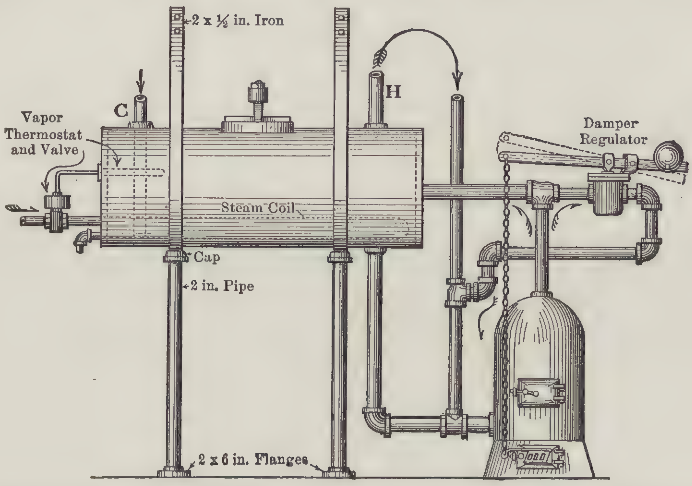


FIG. 144. TANK HEATER AND STORAGE TANK WITH AUTOMATIC REGULATION

small installations and 9000 B.t.u. per lb. of fuel for the larger jobs. Next, find the heat units required per hour. If the water is to be heated from 40 to 160, the rise in temperature will be 120 deg. If 200 gals. are the average consumption per hour, then $200 \times 8.3 = 1660$ lb. of water to be heated. 1660×120 deg. rise $= 199200$ B.t.u. required per hour. $199200 \div 40000$ (5 lb. fuel per foot per hour) $= 5$ sq. ft. of grate surface, nearly, needed in the heater.

Under the tank conditions given above, the mean temperature of water acted on by a coil would be 100 deg., and by the first rule previously given for coils, 200 gals. per hour heated from 40 to 160 deg. would require 13 sq. ft. or 40 lin. ft. of 1-in. brass pipe coil, or, 26 sq. ft. or 78 lin. ft. of 1-in. I.P. Coil. The call for steam equals 80 sq. ft. of direct steam radiation and approximates 6 B.h.p.

Supposing that in the case in hand 200 gals. per hour was the maximum consumption at meal or bath times in a hotel or apartment house job and that not over half of that amount would be used between times. Then, a 400-gal. tank with a heater having $3\frac{1}{2}$ ft. of grate would answer.

The heater would exceed the demand part of the time and the tank would accumulate water for the hours of heavy drawing.

In selecting a heater, decide by the grate surface figured to be necessary. Maker's ratings in terms of "size tank suited for" are not to be taken as the hourly capacity of the heater,—at most, such catalogue ratings can be taken only as a hint that the size tanks mentioned with such and such heaters are, ordinarily, economical sizes to use with them. The smoke flue for a heater should never be smaller than specified by the maker.

Pool Heating by Circulators

If a swimming pool or other tank is to be heated, the method of figuring boiler power or grate surface is about the same as given for tank heaters. Where a large amount of heat is necessary to warm the water up to a stated temperature in a given time, the capacity of the heater can be found by dividing the total heat units required to warm up to the required temperature under the most adverse conditions, by the number of hours that can be regularly allowed to warming of the whole body of water from initial to terminal temperature.

The time allowed for warming up may generally be taken to be the same as the time that may be allowed between complete changes of water in the pool when in regular service. The quotient obtained as above will be the hourly capacity of the heater required.

For example, if 16,600,000 heat units will raise the water in a pool from 40 to 80 deg. and 72 hours are allowed for the initial heating or for maintaining the temperature during each gradual complete change of contents, then, $16{,}600{,}000 \div 72 = 230555$ B.t.u. the hourly capacity of the heater required.

At a fair rate of efficiency, and coal consumption, say 6 to 7 lb. of coal consumed per hour per square foot of grate and a transmission to the water of 9000 B.t.u. per pound of fuel, the heater would, at 6-lb. fuel consumption per hour per foot, require 4.2 sq. ft. of grate surface.

That is, $6 \times 9000 = 54000$; $230555 \div 54000 = 4.2$ sq. ft. A heater with 5 ft. of grate surface, might therefore be taken to be equal to keeping up with the loss of heat through wall and by radiation, and at the same time keep the water up to the required temperature while the contents of the pool was being renewed continually at a rate of once in every 72 hours.

If the water is not to be changed by regular constant induction and out-go, and the interval between changes is unusually long, and there is steam at hand to help out in the initial warming by coils in the pool, or by "blowing in," the hourly capacity of the water heater may be reduced to $\frac{1}{2}$ or a $\frac{1}{3}$ that otherwise needed, because the loss by chance

leakage, radiation and conduction in such jobs can be supplied by an insignificant outfit after the pool water is warm enough for service.

Pool Heating by Coils

A pool contains 4800 cu. ft. of water to be heated to 80 deg. from 50 deg. F. 4800×7.5 (gallon per cubic foot)×8.3=about 300000 lb. of water, which, by 30, the required rise in temperature equals 9000000 heat units needed to warm up the water. 50+80÷2=65, the mean temperature of the coil will act on. With steam at 228, the temperature difference is 163 deg. Taking the brass pipe rate of 125 B.t.u. transmission per square foot per hour per degree difference, 163×125=20375 B.t.u. transmitted per square foot of coil per hour. 9000000÷20375 =441 sq. ft. of brass pipe coil needed to do the work in one hour. 441×2 =882 sq. ft. of I.P. required. 882÷10=88 sq. ft. of I.P. to do the work in 10 hours, and 30 sq. ft. would do it in 30 hours, or 12 sq. ft. of iron pipe would do it in 72 hours.

In a pool, the coil pipes should be large on account of the necessary length of the coil,—1½ or 2-in. pipe is usual. If 1½-in. pipe is to be used, multiply the square feet of coil needed by 2; 2×12=24 lin. ft. of 1½-in. iron pipe needed to heat 4800 cu. ft. of water through a rise of 30 deg. in 72 hours time.

Pool Heating by Blowing Steam into the Water

Again using the 4800 cu. ft. of water, now to be heated 30 deg. by "blowing in." One cubic foot of water weighs 62.5 lb.; therefore 4800×62.5=300000 lb.; 300000×30=9000000 B.t.u. This divided by 955 B.t.u. latent heat per pound of steam at 5-lb. G. P., equals 9424 lb. of steam required to be condensed to warm the water, or, about 270 B.h.p. for 1 hour; 27 h.p. for 10 hours, or, 3.75 boiler horse power for 72 hours. To do the work in 72 hours, about 130 lb. of steam must be condensed per hour,— enough to supply 500 sq. ft. of direct steam radiation. A 2-in. flow pipe will carry the steam. It can be fed to a muffle device purchased in the market, or, blown in through a submerged perforated or branched pipe. The above figures take no account of the additional heat provided through the increment of sensible heat due to the steam condensation cooling down to the temperature of the water in the pool. It is ordinarily just as well to ignore it in calculations and thus let it stand as a good measure item.

CHAPTER XLIX

Bath Room Coils

If it be desired to heat a bath room by means of a coil or radiator connected to the domestic hot service, somewhat as shown in Fig. 146 the following factors of heat loss from the room should be considered:

Assuming the rooms above and below and adjacent to be otherwise heated and the apartment to be warmed to 70 deg. in zero weather, allow 1 B.t.u. per square foot of glass per degree difference between room and weather temperature; 1 B.t.u. for each linear 1-in. of window opening and meeting rail; 0.4 B.t.u. for each sq. ft. of exposed 9-in. brick wall, per degree difference, and 0.5 for each square foot of exposed walls of ordinary frame houses. The weather temperature difference is, of course, 70 deg.

Not making proper allowance for these losses is the cause of so many of such coils not giving satisfaction.

As an example, assume that there are 10 sq. ft. of window glass; 18 lin. ft. of window crack; 134 sq. ft. of exposed 9-in. brick wall with northeast exposure, and 576 cu. ft. of contents in the room,—the contents to change once an hour.

Room Losses Per Hour

Glass, 70 B.t.u. per square foot for 70 deg. temperature difference $=70\times10=$	700	B.t.u.
Crack around window, 18 lin. ft. $\times$ 12 = 216-in.,—equal..............	216	"
Exposed wall, $0.4\times70=28$; $28\times134=$..............................	3752	"
Contents $576\div55=10.4$; $10.4\times70=$..............................	728*	"
Total per hour..	5396	"
15 per cent. addition for N.E. exposure =..........................	809	"
Grand total per hour required in zero weather.......................	6205	"

*The contents of the room is figured thus: about 13.5 cu. ft. of air weighs 1-lb. The specific heat of air is about ¼ that of water; 55 cu. ft. of air heated 1 deg. will therefore require about 1 B.t.u. To raise the air of the room 1 deg. thus takes 10.4 B.t.u. and it must be warmed through a range of 70 deg.

Now for the surface of the coil. A regular radiator will give off about 1.6 B.t.u., and a pipe coil about 2 B.t.u. per square foot of surface per hour per degree difference between the surface and the air of the room. Using a coil and assuming the water will not exceed 150 deg. F., the water temperature will exceed that of the air of the room by 80 deg. Then, $80\times2=160$ B.t.u. transmitted per hour per square foot of coil, and $5975\div160=37\frac{1}{3}$ sq. ft. of coil surface needed to warm the room to 70 deg. F. when the coil surface is 150 deg. F. and the weather zero.

It is easily seen that a small range water back would fail to heat the room while giving any domestic service worth considering; a large back

having 1 to $1\frac{1}{3}$ sq. ft. of surface exposed to the fire would give tolerable service. If a coil back of 1-in. pipe is made for the purpose, enough pipe can be used to meet the requirements, but not without jeopardizing the baking qualities of the range. Where furnace coils or heaters are used in connection with range backs, a small room can be heated satisfactorily, but in such cases there is seldom need to resort to such methods, while for the ordinary residence job, attempting to heat a room from the water back does not often give results worth the trouble.

The pipe sizes are marked on Fig. 146. The coil pipe may be any size preferred. There must be an air cock at the highest point to free the coil of air so it will fill with water. As the water in a domestic system is continually changing, air is always being freed from the water by the heat and there should be a considerable pocket for air to collect in above the coil level so circulation will not be broken too easily. In a regular hot water heating job the air is soon separated and there is little trouble with it after the job runs a week or so, because the same water is circulated from day to day and only a little fresh water is added from time to time.

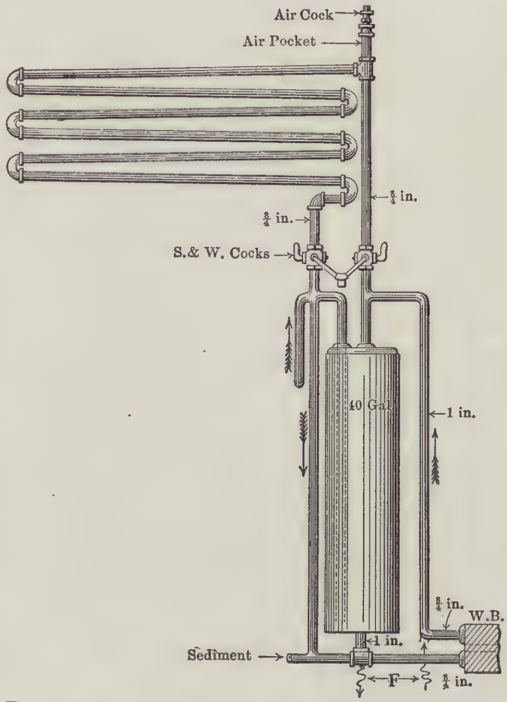


FIG. 146. HEATING COIL SUPPLIED BY WATER BACK

The arrows at the bottom of the sketch indicate furnace connecting pipes.

CHAPTER L

Cooling Coils for Drinking Water

In place of ordinary water coolers, many buildings are fitted with a pipe coil in an ice box arranged to cool the water (for the fountains only) as it passes through. The box is sometimes placed on an upper floor when the feed is from a roof tank. It may be placed in the basement for either city or tank feed. When placed below the fountains, no attempt at circulation is worth the while. The rising supply should be well covered and as small as the usage will permit. When the box is placed above the fountain the leading pipe, thoroughly covered, is often branched into direct for the fountain supplies. In this way usage is entirely depended upon to change the contents of the drop pipe before the water has had time to absorb much heat from the atmosphere. In some cases the drop pipe is carried to below the lowest fountain and then returned again, as a feed-pipe, and connected into the tank supply as shown by the dotted loop in Fig. 150, in which **D** is a drain; **FF** fountain branches, and **CK** a check valve. The check prevents the feed to tank from delivering warm water direct to the fountains and the loop is supposed to allow the water to recirculate through the coil when it becomes warm, but it is doubtful if the benefit so derived is worth the cost of the *check valve.* The author prefers a simple drop pipe feeding direct. If it is desired to provide some surplus for hours of heavy drawing, the cubic capacity of the coil or the drop pipe (preferably the former) can be made to hold it by increasing the linear feet of the regular coil pipe, or by putting in a ring of much larger pipe at the bottom of the coil to act as a container. The cooling power of the coil per hour should at least equal the average hourly consumption.

A cooling coil is merely a heat absorption arrangement in which the ice in the box abstracts the heat from the water in the coil, just as cold air in a room in winter absorbs heat from water or steam in the radiator of a heating apparatus.

In a fountain subject to severe duty it may be assumed that water to fill a $\frac{1}{2}$-pint cup will be drawn every 10 sec.,—6 drinks per minute or 360 per hour, say $22\frac{1}{2}$ gals. per hour. $22.5 \times 8.3 = 187$ lb. of water to be cooled per hour. If the supply be taken to be 60 deg. F. and it is assumed that the temperature of the coil in the presence of ice will fall to 34 deg. F., then $60—34 = 26$ deg. temperature difference. Allowing the water in the coil to give up 1.5 B.t.u. per square foot of surface per hour per degree difference of temperature, the cooling effect per square foot of coil surface per hour will be $26 \times 1.5 = 39$,—say 40 B.t.u.

One pound of water cooling 1 deg. gives off 1 B.t.u. There are, as indicated above, 187 lb. of water to be cooled per hour from 60 to, say 40,—20 deg. $187 \times 20 = 3740$ B.t.u. required to be absorbed per hour to *cool the water* ($22\frac{1}{2}$ gal.) for one fountain, when one $\frac{1}{2}$ pint drink is drawn every 10 sec. 3740 divided by 40, the hourly rate of cooling per square foot, equals 93.5, say 93 sq. ft. of surface needed to cool the water. One cubic foot equals 7.5 gals., so 3 cu. ft. of contents will be required in the coil to lengthen the change of coil contents to one hour. Two-inch pipe requires 43 lin. ft. to hold 1 cu. ft., and 1.6 lin. ft. to equal 1 sq. ft. of surface; $1\frac{1}{2}$-in. pipe takes 70 ft. and 2 ft. per foot of surface; $1\frac{1}{4}$-in., 96 ft. and 2.3 ft.; 1-in., 166 ft. and 3 ft. per foot of surface, and $\frac{1}{2}$-in., 472 lin. ft. per cubic foot of contents and 4.5 lin. ft. per square foot of surface. Therefore:—

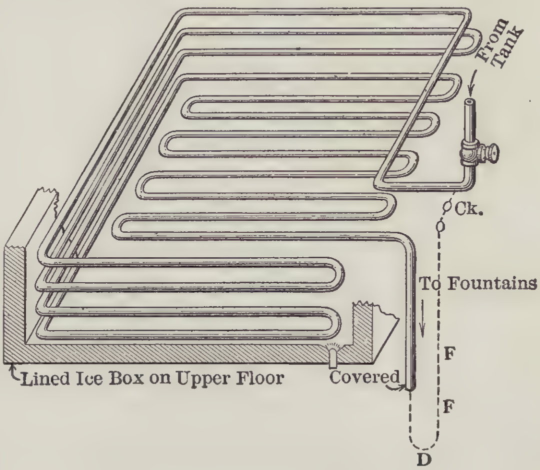


Fig. 150. Drinking Water Cooler

129 lin. ft. of 2-in.	holds $22\frac{1}{2}$ gals.	and equals	80 sq. ft.	surface
210 lin. ft. of $1\frac{1}{2}$-in.	holds $22\frac{1}{2}$ gals.	and equals	105 sq. ft.	surface
288 lin. ft. of $1\frac{1}{4}$-in.	holds $22\frac{1}{2}$ gals.	and equals	125 sq. ft.	surface
500 lin. ft. of 1-in.	holds $22\frac{1}{2}$ gals.	and equals	166 sq. ft.	surface

Suppose it be most convenient to use 1-in. pipe: Then, irrespective of cubic requirements of the coil, the 166 sq. ft. of surface in 500 lin. ft. would cool the water proportionately quicker,—93 is 56 per cent. of 166 and 280 is 56 per cent. of 500. Therefore 280 linear of 1-in. might be allowed for cooling the water if it is thought the reduced cubic capacity will permit the water to get cold enough. Ordinarily, $1\frac{1}{2}$ or 2-in. pipe would be used under such conditions.

A 2-in. plank box, lined and covered, will do for the ice box and is quite usual, but where the plant is large it pays well to construct the box with multiple walls, with air spaces or mineral wool filling, much as grocery ice boxes are made.

For the capacity mentioned, a $4 \times 3 \times 3$ ft. box equaling 66 ft. of exposed surface is a good size. If 0.5 B.t.u. per square foot per hour per degree difference in temperature be allowed for a 2-in. lined box and the weather is assumed to be 80 deg. F. and the inside temperature, 34 deg. Then, there are 46 deg. difference and the box gives 23 B.t.u. per square foot per hour. $66 \times 23 = 1518$ B.t.u. per hour required for

the box. $1518+3740=5258$ B.t.u. total per hour. Considering only the latent heat of ice available (144 B.t.u. per pound) $5258 \div 144 = 36.5$ lb. of ice per hour, or 876 lb. per day for constant use for 1 fountain, as in a depot or hotel lobby, using $22\frac{1}{2}$ gals. per hour under the conditions mentioned.

The above quantity of cooling surface may be taken to be sufficient for from 6 to 12 fountains on ordinary office building floors. $\frac{1}{20}$ to $\frac{1}{25}$ as much surface will do for a single store-office or large residence fountain. $\frac{1}{4}$ to $\frac{1}{2}$ as much surface will answer for dry goods store fountains. 20 ft. of $\frac{1}{2}$-in. pipe will answer for family use where a city water connection is made to a coil in the ordinary refrigerator. Tin pipe is best for drinking water coils, but brass and galvanized iron pipe are used, as a rule, for all but private house and soda water coolers.

The drain pipe from ice boxes of any kind should not connect direct to a soil or waste pipe.

The loss through the bottom surface of the box may be reduced by letting the drain pipe extend up enough to keep the bottom of the box well covered with ice water. The ice may lie upon a slat grid above the water level; if carefully laid in, it may lie on the coil in small boxes, the water level being such as to cover the bottom pipes and touch the ice. The best arrangement is probably to put the ice on a slat grid above the water and allow an inch or so water depth in the box.

Whether the feed is upward or downward through a coil is generally settled by the location of the box, but a little better service will result from feeding downward, even though the box is below the fountains.

PART III

CHAPTER LI

Bath Tubs and Trimmings

In the days of wood-case baths the outside length and breadth of case was not far more than the extremes of the bath proper measured inside and the difference a rather constant quantity. The case measures were therefore used as the nominal length of both, and the plumber added for his *outside* casing. With the advent of iron baths the cataloguing of inside measures was first practiced. In this way the error, with reference to measurements over all, was increased for the iron rim stood for both the lining case and the outside casing. With the multiplication of rim widths which soon followed confusion increased. It was necessary to know the rim width in order to find the measure overall. When some makers changed tactics and used the over-all dimension for the nominal size, the situation was worse, for it was then necessary to know both the width of rim and the maker before the length of a tub could be approximated. To keep workmen posted as to the roughing in of each job was no small task. The trade therefore has reason to be thankful that the universal practice now is to catalogue the over-rim measure as the nominal size. The little variation from catalogue sizes due to bulging or closing of the sides under the heat of enameling is of no great practical consequence for no tub should ordinarily be set so close that a half inch or so play is not available.

In disposing the fixtures for a bath room, it should be borne in mind that: The best position for a tub with fixtures at the foot-end, is with the foot against the wall and body of the tub projecting into the room; that where possible, $1\frac{1}{2}$ in. at side and 4 in. at the fixture end should be left between the tub and wall; that fixtures may be placed at the side, on tubs that are ordinarily end-fixture tubs,—can be ordered so or so drilled by the plumber if desired; that outside finish on the side next to the wall is not essential; that makers will sand-blast the outside of a tub, for a small price, so it can be outside-finished on the job, if so ordered; that court proceedings decree that the damage due on a defective tub is to be based on the condition in which it was purchased, and that whatever decoration a purchaser places on a tub purchased unfinished is lost to the buyer in case of defect; that side fixture tubs should, if possible, have neither end against an end wall; that tubs having fixtures fitted through the rim, need no allowance of room for fixtures to stand in; that twice the width of rim must be deducted from the

nominal size to get the inside length; that the smallest tub that will answer is best for jobs where water must be hand-pumped, where storage capacity is limited and where fuel to heat with is abnormally high; that flat bottom tubs like shown in **R**, Fig. 166, are easy to stand in but take a deal more water to make a little depth, than does shape **S** in the same sketch, and leaves more scum on the surface when emptying; that hot and cold water should be mixed (for a bath) before it falls into the tub; that with water and person added, the average iron tub weighs 1200 lbs. and porcelain tubs 2000 lb.; that it may be necessary to remove the tub for renewal, or repairs of the piping; that the freer the interior of a tub is of fittings, the more convenient; that a vessel cannot be filled at a bell supply fitting; that for close quarters, the end

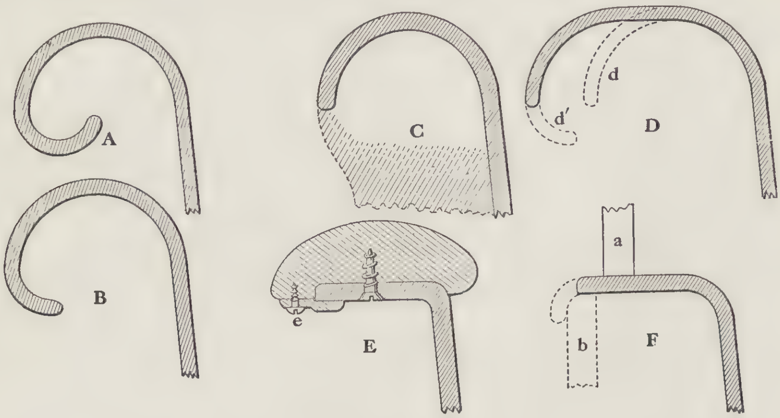


Fig. 160. Enameled, Porcelain and Wood Bath Rims

of a lavatory may hang over the tub rim, when plug and chain are used on the tub, and that a lavatory may extend to the end of a low tank or even a little nearer to the closet, when a high tank is used. Bearing these points in mind, the reader will see much between the lines in the following brief references to the sketches herewith.

In Fig. 160 are sectional sketches of the different styles of bath tub rims. Sketch **A** shows the "full under-roll" rim of iron tubs, used only on large rims. The "half under-roll" is shown by sketch **B**. A plain roll rim is shown in **C**,—it has about superseded **A** and **B**, because it is much easier to cast. Large rims serve no purpose beyond looking massive and being a little easier on the person in getting in and out, and using it as a seat. Continuing the solid line, the dotted line in sketch **C** completes the contour of the usual top edge found on solid porcelain tubs. In sketch **D**, the solid line shows a form of rim used on some tubs; extended as per dotted lines **d′**, it forms another market pattern rim; either may constitute, in connection with a narrower rim on the sides and head end, like indicated by **d**, what is known as an

extension rim,—a plan of making the rim of a narrow rim tub wide enough at the foot to fit the fixtures through the rim instead of letting them stand behind it. At **E**, the iron rim, undrilled, shows a form much used in the early career of iron tubs; the rabbeted wood rim shown over it constitutes what was long considered a standard rim,—then much preferred to the iron rim and one that *is* far more gracious to the touch, though it is open to the charge of contributing to produce unsanitary conditions. Oil finished hard wood bedded on putty was used for wood rims. They were attached by wood screws run in through the iron rim from the bottom, as shown in the sketch. Metal clips, as at **e**, were sometimes depended upon to hold the rim on, but oftener; both screws and clips were used. For recess tubs with the wall edges extending into the wainscoting, flat rims are used like shown in sketch **F**, **a** representing the tile wall. If an iron tub is to be concealed at the front by tile or marble, as indicated by **b**, the rim is cast with a round corner so that the edge hugs the face of the concealing wall as dotted in the sketch. But few tubs are so walled, the general practice being to bolt and putty to the tub wall a false front of iron of the form desired. The plumbers are not in love with these imitation porcelain tubs, as the false plates are fitted on in the factory and are easily jolted so they have to be returned to the factory for refinishing, usually bringing a loss to the plumber, though the tub may have been damaged in shipment and, being boxed, not seen until opened at the building.

Iron baths are not often porcelain enameled on the outside, on account of the difficulty of adjusting the fusing temperature of the various coats of enamel, so made necessary, in a way that will produce a good lasting enamel and yet not mar the finish of one side in securing the finish for the other. It is for this reason that an outside zinc white finish of many thin coats is dried on to the iron surface, which in factory work is first perfectly smoothed. A few tubs have by great care been beautifully finished by fusing enamel on both the inside and outside.

In sketch **G**, Fig. 161, a waste is shown fitted through the rim; **a** is the lift pipe carrying the waste washer or plug which retains the water in the tub; **a′**, overflow holes in lift-pipe; **c** and **c′**, top piece of the casing pipe,—it has recess slots and notches to take a pin on the lift pipe so the lift can be locked off of the seat to let the water run out; **b** is a saddle piece fitting the rim, and upon the upper end of which hangs the flange of **c**; **d** is a counter saddle used under the rim, **b** and **d** being clamped to the rim by a lock-nut **b′** run over a thread on the shank of **b**. **c** is lock-nutted down by the nut screwing over **c′** (shank of **c**). **c′** is threaded on the interior to receive the casing pipe, as shown; a long thread on it, and one on the lift pipe, being the means of adjusting their lengths so the lift head **a** will work properly in the channels of **c**. The out-of-wall

to out-of-rim measure **L**, in **G** and **H**, varies at different points according to the pitch of the wall,—in ordering special fittings for a tub in stock, this pitch must be stated. When the waste stands behind the rim, as in **H**, the waste is similarly made, but the provision for fastening to the rim consists of a band over the casing pipe with a rod extending to the end wall of the tub. The rod is made long enough for any width of rim, and has a long thread at the tub end; a sleeve lock-nut and counter-slant washer are used outside of the tub wall. The rod is sawed off by the plumber to suit the tub rim and the interior button drawn up in putty,—all about as shown in sketch **G**. In some fittings, the button and nut are tapped square and the washer omitted. For these, the plumber bends the rod to counteract the tub wall slant, lets the band stand a little lower on the waste and draws up the support with the end of the rod perpendicular to the wall of the tub. Standing wastes are used on tubs drilled for patent overflow, by using a button large enough to cover the overflow hole; in such cases it is best to screw up the nut and button in red lead or litharge mixed with shellac varnish.

In sketch, **I**, **L** indicates what is taken to be the width of rim; the interior length begins at **M**. A patent overflow for connected waste is shown attached to the rim. The overflow pipe is held to the tub by a chain-stay bolt screwed through the grating into a cross bar as indicated at **b**. The grating should be cast brass and have a rabbet for the overflow hole,—spun gratings are too weak, and with the abominable paper-weight trimmings having imitation threads wrinkled in the metal, should be relegated to the scrap heap, for no self-respecting plumber will palm them off on unsuspecting customers.

When top nozzle supplies like shown in sketch **K**, or bell supplies like in sketches **L** and **O**, or double top cocks like **M** and **N**, Fig. 162, are used, it matters little what sort of curve the foot end of a bath has, as neither the curve of the wall nor that of the rim affects the fittings nor confines the plumber to a special make. When a cock is used in the tub, as at **J**, the foot end should be straight for a distance sufficient to take the cock flanges, for it is not a pleasant or profitable job to bend the body of a common double bath cock, and but few patterns of cocks are made curved.

With 3-in. and narrower rims, the waste usually stands behind the rim as in **J** and **M**. If a patent overflow is used, such rims include the length necessary for fittings as indicated by dotted lines in **J**. If a bath cock of the usual $3\frac{3}{8}$ or $3\frac{1}{2}$-in. centers is used, offset supplies are almost necessary and are always better. Straight down pipes do very well when the spuds of the cock are 4-in. center to center and used with a standing waste which gives more room between the supplies and the waste connection. A double cock is necessary for bath use in order

to temper or mix the water as it falls in the tub. Though more used than other supply fittings, cocks set as in **J**, take up room in the tub, interfering seriously in short lengths. **M** and **N** show two modifica-

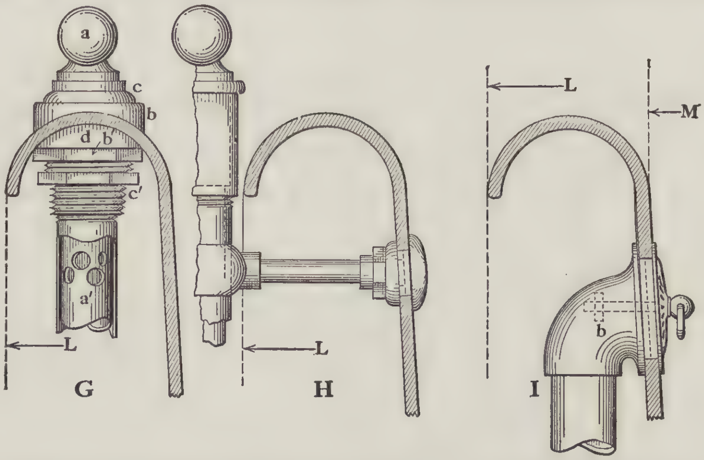


Fig. 161. Length of Bath Tubs Over Rim,—with Fittings through and behind the Rim

tions of ordinary compression bath cocks, permitting their use over the rim where they interfere less with the interior of the bath.

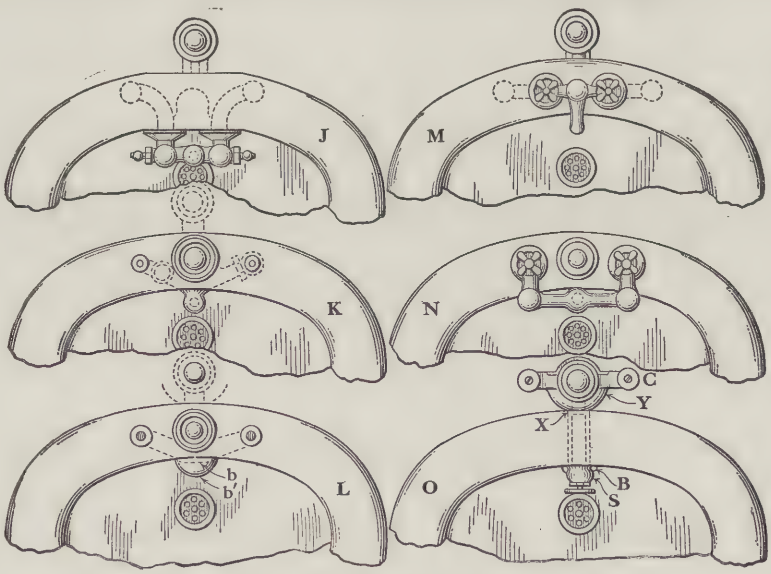


Fig. 162 Plan Views of Bath Tub Foot Ends

A top nozzle supply is shown in sketch **K**; it is perhaps the best of all so far as concerns giving room in the tub. It provides a drawing point in the bath room for large vessels, as do cocks; furnishes a thread

end for spraying hose. Its general stability, and adaptability of the valves to any form of rim make it a superior fitting. The valves have a swivel connection to the water-mixing yoke, and may thus be used behind the rim or through the rim of any curve, regardless of whether the waste is through or behind the rim. In sketch **L**, a bell supply and waste are shown fitted through the rim; dotted line **b** indicates the button of the rod and band that would be used, at about the overflow level, to hold the waste steady, was the waste standing behind instead

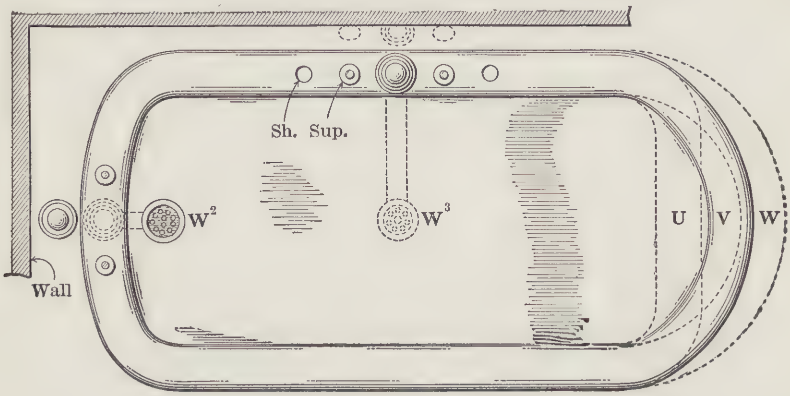


FIG. 163. BATH TUB SHAPES

of through the rim; **b′** is the delivery bell of the supply fitting,—the water issues from a slot in its tub edge at the bottom. There is little splash or noise from the start when a tub is filling from a bell and the action is

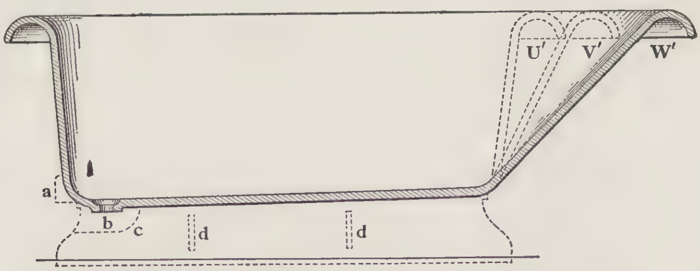
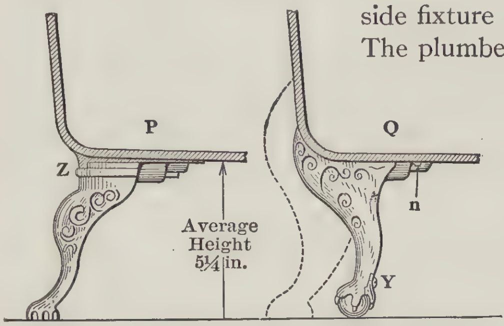


FIG. 164. BATH HEAD SLANTS; BOTTOM "FALL," AND BASE CASTINGS

silent after the bell is submerged, but, no water can be drawn into vessels from it. Sketch **O** shows a 3-valve fitting—hot, cold and shampoo—fitted behind the rim as would be necessary for a porcelain bath. **C** is a valve wheel; **Y**, the yoke; **X**, bell connection, from yoke; **B**, bell; **S**, shampoo valve. For a porcelain tub with base the waste hole would be in the end; if on legs or blocks it can be in the bottom, as shown. There are numberless bath fitting designs for special work or to suit certain tubs but those mentioned may in general be considered standard.

The foot ends shown in Fig. 162 belong to what may be termed the "modified French pattern." The plan of rims is further shown in Fig. 163. The solid rim line **V**, indicates the modified French shape of bath with side section like **V′**, Fig. 164; it is generally fitted with end fixtures; a modified Roman pattern is made with both ends curved like **W**,—it also has a side-section like slant **V′**, Fig. 164, *at both ends.* Such are regularly fitted with side fittings, with waste hole ($\mathbf{W^3}$) at the center of length. The regular Roman pattern, in plan, is at both ends, more like the dotted form **U**, and has a side section like **U′**, Fig. 164, *at both ends.* The French head end is shown in plan by **W**,—the whole rim now being in plan about the shape made by dotted **W** taken with the solid sides and end of Fig. 163 and the side section agreeing with solid lines **W′**, Fig. 164.

Bottom waste holes are employed for both leg and base tubs with end fittings as indicated at $\mathbf{W^2}$, Fig. 163, and **b** Fig. 164. Shampoo or shower supply holes may be bored in the side rim of either an end or side fixture tub, as shown at **sh**, Fig. 163. The plumber need not hesitate to do this as occasion suggests, though it is less risk to order a tub drilled as wanted.



BOSS LEG LEAF LEG
FIG. 165. BATH TUB LEGS AND THEIR MERITS

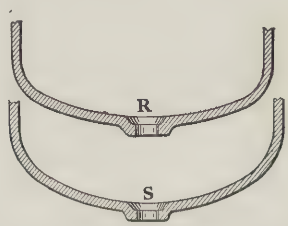


FIG. 166. CROSS-SECTION OF FLAT AND ROUND BOTTOM BATH

Iron tubs with base in place of legs, like dotted under in Fig. 164, are not uncommon. An overhanging bead is cast on the tub bottom to receive the base; one or two stiffeners, according to length of tub, are cast across the length of the base, as dotted at **d**, **d**. Bases are set on the surface when used on wood floors, but where the floor is tile or terrazza the base should be leveled, and blocked interiorly in place, with the bottom edge ½ in. or more below the floor surface level. In some forms of end fixture tubs with base the waste is at the end as at **a**; in others a depression pocket is cast in the end wall of the base at the foot, as at **C**, Fig. 164, so as to give room to attach the waste pipe to a hole at **b**.

In Fig. 165 sketches **P** and **Q** represent the two general forms of bath tub legs. The sketches are not literal, being intended to show only the main features. The leg in **P** is fitted into a housing rib (**Z**) cast on the

tub. It is attached by a bolt through the top end of the leg or by wedging under a tongue projecting into keepers. As far as cleanliness is concerned this is the best form of leg made, but practically no adjustment of height can be made to make up for unevenness of floor or warp in casting. The greater the floor bearing, the better for tubs set on wood floors. When the bearing surface is small a tub is more likely to settle out of level. Legs with ball feet are therefore not suited to any but hard surfaces like tile, cement, hardwood, etc. Iron feet frequently stain the floor. While iron legs are usual, a claw foot design grasping a ball, as shown in sketch **Q**, has been the general means of obtaining a non-corrosive bearing surface,—a loose ball of glass, brass or marble being slipped in through claw-marks or fitted into a socket in the foot by removing a screw-attached claw, indicated at **Y**. Imitation ball feet are numerous. The style of leg shown in **Q** is most usual. The leaf in most patterns covers side wall curve surface. The objection to such is that dirt accumulates behind the leaf. In the large corner legs for Roman pattern tubs, the leaf is much larger than on side legs, as indicated by the dotted line. Leaf legs are usually secured, like a stove leg, by a tapering tongue wedging into doves,—to prevent the tongues from loosening a cut nail is driven in a channel, over the tongue. Slotted tongues bolted to doves have been used with leaf legs arranged so the curve of the leaf would rotate on the curve of the tub, in order to secure adjustment of height.

CHAPTER LII

Shower Bath Work

While tub baths are more satisfactory for general service, are essential for some purposes, are far more extensively used than other forms, and will never be dispensed with, they are not of late years regarded with unreserved approbation, especially for the regular service of institution work. There is a chance of transferring skin affections, and the process of tub bathing is not one to insure cleanliness unless care is taken to rinse the body with a spray. In the shower bath, for which there are arrangements of many forms, the water is continually renewed throughout, in as pure a state as the initial supply, while in the tub bath the condition of the water is changing for the worse from first to last. The tub bath is at its best in residence service where the users and their condition are known, and where the cleansing of the tub surface between baths does not rest with attendants who may be indifferent. Many residence jobs have both shower and tub arrangements. The shower may be in connection with the tub, using the tub as a receptor for the spray water but, in the best sense, the shower is an independent fixture. Receptors are purchased for most residence jobs, but the greater number for other buildings are built up on the job. Some plans that have been followed are shown by the sketches in Fig. 170.

Job Built Receptors

Various dimensions are assigned to the shower space proper, according to space, nature of the job, whether the entire room containing it may be taken as a dressing room, or the dressing room cut off as a part of the shower arrangement. A robing space with seat is usual, from which the person can step through a curtained door opening onto the receptor floor. The robing space varies from 30×48 inside to larger, with the entrance on the narrow side and shower opening in one end of the wide wall so as to leave room for a built in seat. The door opening is provided with a rubber or duck curtain pending from a rod across the opening and hanging down inside the threshold. If the receptor is built in instead of planted on the floor it is generally sunk with reference to the robing floor level, even though raising of the robing part is thereby necessary. The receptor space may be anything from 36×36 up, 36×42 being considered the minimum for decent jobs.

In No. 13, Fig. 170, the shower and dressing room are shown at the same level. The base of the receptor walls is simple wainscot coping, **(C.B.)** single for side wall and double for partition use, as shown. The floor is tile or terrazzo. Tile coping base like shown can be purchased,

cut from marble, or, for marble thickness, tile base may be doubled for partitions, and out-set at the wall for wall use. Water proofing under the compartment is considered essential. There is nothing better for the purpose than sheet lead. If the work is built above wood floor beams, on rough floor as shown in the right half of No. 13, it is a good plan to mix some glycerine with the floor facing to increase its resistance to water. Three inches thickness, including the tile and its facing or bedding is sufficient. How far the lead or water-proofing is carried beyond the threshold of the door opening is a matter of discretion. If there is any convenient open place it adds to the certainty of confining

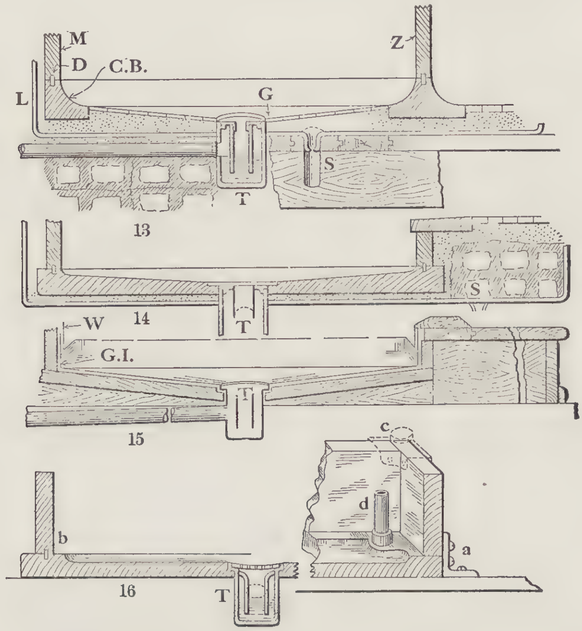


Fig. 170. Shower Compartments, Bases and Receptors,—Job-Constructed

seepage or leakage, to put in a safe pipe **S**. If depth is available, the water-proofing should be below the waste when the waste takes a lateral course. On the wall sides the water-proofing should extend above the coping joint as at **L**. The shower waste trap is usually in the center of the floor, the floor pitching to it 5 deg. or more from every direction, as indicated. A special form of brass drum trap, marked **T** in the sketches, is best. The outlet governs the water level. The seal is accomplished by a central dip pipe with a threaded flanged head screwed into the body in a way to make it air tight but still removeable at will by first unscrewing the strainer. In this way the waste is more or less accessible, the body of the trap can be cleansed and the dip pipe is ready for quick inspection or renewal. The trap body is soldered to the lead and ex-

tends below the floor, or down in the fire-proofing. The strainer screws into the body, **G**, set flush with the tile surface. Supposing the walls of the compartment to be marble, the wall slabs **M**, and jambs on the door side may be doweled to the base, as at **D**, and otherwise set as plumber's marble work, using between the joint surfaces a cream of litharge or red lead mixed with glycerine. When the shower and robing space floors are on the same level, an upright sill is placed in the door opening between the jamb pieces; the top edge of this sill or threshold piece is shown at **Z** in the sketch.

In sketch No. 14 the shower floor is a slab of marble, 2 in. to $2\frac{1}{2}$ in. thick and deep countersunk to the center, bedded on cement in the safe pan which extends out under the threshold, as shown. It is otherwise fitted as before described. The robing space has an elevated floor, with over-hanging threshold or sill set flat as seen in the sketch. A line of webbed fire-proofing material is laid in as shown, to fill; it is broken out in the bottom to provide water access to the safe pipe, when such is used.

In sketch 15 a sheet metal shower compartment floor and lining are indicated, the shower proper being set below the robing floor by cutting the original construction or dapping out the dais timbers. The sump so made is rough floored and lined with galvanized iron (F.I.) as indicated, the sill, of carpet-strip form, being covered with sheet metal turned down inside to below the top of the bottom edge of the floor metal. The side walls (**W**) are covered to any height desired, usually 7 ft., with galvanized iron or zinc. The bottom edge of the sides projects below the top of the base metal. None but the pan of the shower space needs to be soldered. In some jobs the side lining is lock-seamed to the pan and solder-tacked at the corners.

In sketch 16 a job built marble receptor planted on the floor is shown. The sides are 5 in. to 8 in. high fitted as before mentioned. The inclosure is entirely of curtain goods held up by legs fitted into rail-standard fittings on the corners of the marble work, as dotted at **C**, or screwed into inverted caps drilled and screwed down on cement at **d**.

Channel angles are necessary at **C** when rail fittings are not used,—for dowels, as at **b**, are not alone stiff enough to hold the sides. Either interior, or exterior angles at **a** are needed to keep the frame and base together,—they may reach to the floor, set upon the base extended, or on the surface above the countersink, inside.

Market Shower Receptors

With all the foregoing, as with cast receptors, some form of overhead shower,—a hinged or rigid douche head or a perforated ring, or both are used. Any lateral spray or needle baths may be inset in any form of receptor but such are commonly fitted only with marble inclosures, or curtained receptors like shown in Fig. 171, in which **R** is a

vent on the douche, allowing it to drain; **P**, a perforated shower ring; **S** and **S′** pulls with chains to self-closing cocks controlling douche and ring; **C**, inclosing rubber curtain hung to a large ring provided as part of the shower fixture. The style shown in Fig. 171 is like the shower fixtures used in connection with bath tubs. The receptor is 36×36 in. or larger, 6 in. to 8 in. deep; these are made with roll-rim, in porcelain and enameled iron, on legs and with base as indicated at **b**. Some receptors are provided with supply and waste fittings of the same pattern as used on bath and foot tubs, as indicated in the sketch. Shower pipe feet are either screwed to the rim of the receptor, or hooked over it as at **F**. The shower, its standards, valves, etc., should be within the curtain, where the person can have full access to every part. Feet like shown at **F** permit the curtain to hang outside of the fixture and yet dip within the receptor wall,—not possible with the legs of the frame standing on the rim.

Safety Shower Valves

The chief point of shower valve arrangements is to combine safety with the usage desired,—that is make it impossible for the user to scald himself through ignorance or carelessness. A simple and effective arrangement is shown in Fig. 171. The ball body, **M**, serves as a mixing chamber; **V.V.** are valves on the hot and cold supply; **U. Ck**. are union check valves preventing the return of either supply through either pipe; $\mathbf{V}^2$ is the safety valve which operates to control and regulate both supplies. When $\mathbf{V}^2$ is closed no water can pass, though **V.V.** are open. Opening $\mathbf{V}^2$ first turns on cold water only; by continuing to open it hot water is added,—further opening increases the proportion of hot water until both hot and cold are supplying equally; by continuing to the utmost, further opening of $\mathbf{V}^2$ increases the percentage of hot water delivered until none but hot water flows through,—the cold having been cut off. $\mathbf{V}^3$ is the shampoo supply; $\mathbf{V}^2$ must be opened to get water to it. Thermometers are fitted in some forms of mixing chambers.

Sitz and Foot Baths

Fig. 172 is a sitz bath, a familiar fixture of the more complete bath rooms. It is often also pressed into service as a foot tub, and is frequently fitted with a bidet jet as at **b**,—**d** being a douche wash. When these jets are supplied, they are fitted in the waste hole, as shown. In the back wall is fitted, when ordered, a wide spray known as "liver-spray" from its application for liver affections. The regular supplies for a standard fixture are of the bell pattern, which with the waste may be fitted either through or outside of the rim. In the "five-valve" fixture, the valves shown on the left may serve as marked. One for hot douche or hot liver spray; one, cold supply to one or other; and, the other, cold to the bidet jet. Bidet jets are also frequently fitted to shower fixtures,

but separate bidet fixtures are rare, and the jet is now seldom attached to closets, though once it was quite a common adjunct to water closets. Sitz, seat or hip bath fixtures are made in solid porcelain and enameled iron ware, on legs, as shown, and on bases.

Drinking Fountains

Before the public drinking cup fell into ill repute quite a number of drinking fountains had been marketed to meet the call for different locations, some of which will now find little sale because of not being adapted to use with the cupless jet. Many arrangements for extending and securing the supplies of present fixtures in a way to operate a bubbling jet, embodied in the extension, so the old bowl will take the waste are now in use. A distinct fixture attending the abolishment of the cup is seen in Fig. 173,—it being a pedestal with bowl, concentered with and over which is the drinking jet. The supply and waste both rise through the pedestal as shown, the sup-

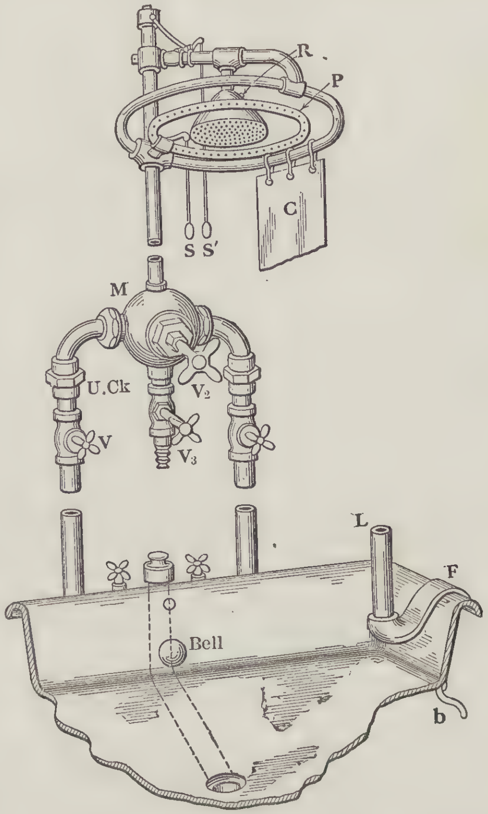


Fig. 171. Shower Supply Fittings and Enameled Cast Iron Receptor

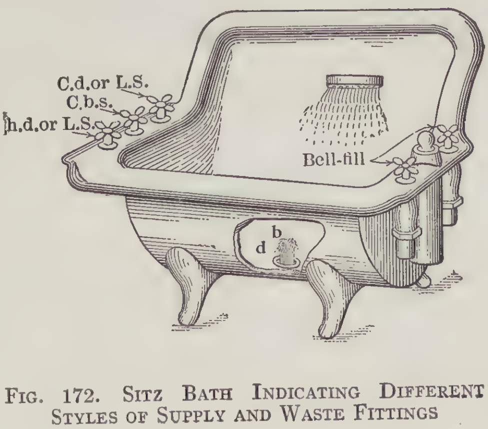


Fig. 172. Sitz Bath Indicating Different Styles of Supply and Waste Fittings

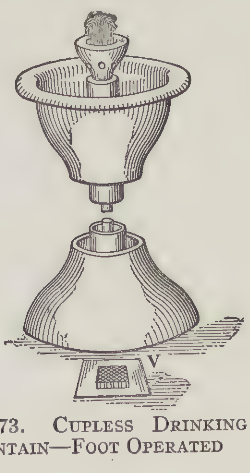


Fig. 173. Cupless Drinking Fountain—Foot Operated

ply pipe being within the waste and terminating in a china nozzle adapted to giving a gentle bubbling issue of ample volume to drink from without touching the lips to the fixture surface. The nozzle cup wastes into the bowl which in turn delivers the waste water into the waste pipe.

Where the water pressure is variable, as in direct systems using added pressure for fire purposes, and in stand pipe systems where the level of the water changes enough to make a material difference in the pressure, and in all cases where foot valves are used to operate the jet as needed, the supply should have a regulator. In the simplest form this may be a restricting washer reducing the opening at any point to a degree where the jet will be right when the valve is on full. This does not regulate varying supply pipe pressure, but cuts out the excessive flow possible under a given pressure. The ribbed section at **V** in the sketch is the foot pedal. It moves in the frame indicated, below which is the supply valve.

CHAPTER LIII

Lavatories

Fewer marble lavatories are now used than formerly, though, including onyx, they are still favorites in the most expensive work, for exclusive designs cannot be had so readily in any other suitable materials, and many do not relish fixtures of precisely the same design as that offered to every person able to pay a modest price. Porcelain and enameled iron have the greatest share of favor in the better grades of work, especially where exclusiveness is not a feature. Each material has its faults and virtues:

Marble lavatories may become stained or broken and have joints at the bowl and back unless cut from the solid; if well fitted, the joints need not be considered a drawback; the bowl can be renewed at small cost and will stand cleaning with any mixture, while the whole fixture is subject to a wider range of treatment in size, trimming and design than any other.

Enameled iron lavatories are practically confined, in design, to the patterns for which there is a more or less general call and are therefore seldom or never exclusive. The enamel will not stand rough handling and is likely to be pitted by acidulous liquid, in cleaning or otherwise. A fracture of the enamel ends in a new fixture being put in. They can be had in every essential design, are cheap, have no joints and are easily supported by the means supplied.

No surface is superior in beauty to that of porcelain ware and it is not easily affected in cleaning; it may have the real massiveness, as well as the massive appearance so desirable in the appointments of substantial structures, and yet the weight and appearance of fixtures made for the regular routine of office and residential work is in accord with the environment. Not necessarily being the offspring of expensive special patterns, specials in porcelain lavatories can be had without serious delay and are therefore accorded their share of the honors in exclusive design work.

Earthenware round bowls of hemispherical section, like in Figs. 175 and 176, the awkwardest of all shapes to wash in, were the first type of lavatory bowls. For a telescoping lead pipe, puttied connection, an outlet nipple, as at **D**, Fig. 176, was provided, the water being retained in the bowl by a circular rubber stopper fitting the opening **C**, while as a strainer, a cross-bar was made integral in the bottom of the plug hole at **X**. Two ears with holes, indicated, were provided on the nipple as a means of wiring the waste pipe to the bowl to support the pipe and to

keep the putty joint sound. A horn overflow, indicated in plan at **B**, Fig. 175, and in elevation at **B′**, Fig. 176, was the common means of preventing overflow while the stopper or plug was in place. This form of overflow was handed down through succeeding shapes of bowls and is still used to some extent,—requiring a waste branch from above the trap to the horn, and a very objectionable form of putty joint.

The "patent" overflow shown at **A** and **A′** is merely a channel connecting the overflow holes with the waste nipple below the stopper. The patent overflow in one form or another is now nearly altogether used on all forms of bowls except those for standing wastes, which provide the overflow and stopper independent of the bowl.

Metal plug basins are now largely used, having the overflow arranged like shown in the detail sketch over Fig. 176, **C′** being a countersink in the bowl surface for the flange of the metal plug or frame and **D′** a flat face for the gasket and locknut holding the plug in place. Metal plugs are made in two styles,—for bowls with and without overflow. A plug for the former type is shown in Fig. 177. It has holes (**OO**) in the wall, through which water from the overflow channel enters the waste pipe; above these is a metal grid or cross-bar, indicated, which serves as a strainer; **P** is the stopper hole; plugs with either metal or rubber stoppers can be had as desired; **L** is the locknut for drawing and holding down the plug water-tight on a bed of putty placed under the plug flange; a gasket under **L** is necessary, to prevent leakage, to make up for unevenness of the surface, and if the bowl is earthenware, to cushion the lock-nut strain; **T** is the tail-piece and **C** its collar.

Fig. 178 shows an oval bowl, much easier to use than the cramped space of a round bowl; **B**, Fig. 179, is a section on its width and **b** a section front to back, both cutting the center of the waste. The bowl shown is without overflow, but is also made with the various styles of overflow, both as a separate bowl and when made integral with the slab.

A happy adaptation of the oval bowl, designed to accomplish one good purpose, and destined to also serve another as well is the "D-bowl" illustrated in Fig. 180. When waste pipes discharge to the floor the further back they reach the floor the better,—the center outlet oval bowl places the connection far from the wall, as does a round bowl. The modern way of exposing pipes made this a point worth considering, though it was of no consequence when lavatories were boxed in. Standing wastes, too, need a longer connecting piece from the bowl hole to stand pipe when the outlet is in the center (**a′**) of the oval, and with iron lavatories the overflow channel coring to a center opening is an item.

Through the combined influence of these facts, the D-bowl came to be a very generally used shape.

A cross-section of Fig. 180 on line **AB** is shown in Fig. 181, in which

the overflow channel is also indicated by dotted lines. The two figures together give a very good idea of the shape of the average D-bowl.

The crescent or kidney bowl shown in Fig. 182 is an improvement on the oval and D-bowls; it allows the arms of the user to flex quite naturally. When with a vertical back wall giving a section like shown

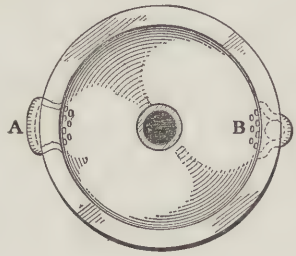


Fig. 175. Plan View of Round Bowl

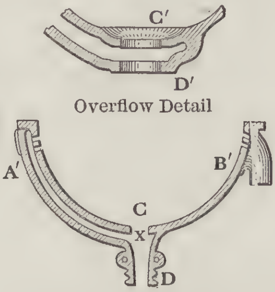


Fig. 176. Section Showing Different Styles of Overflow and Outlets

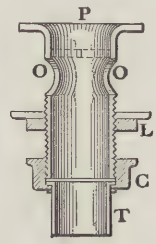


Fig. 177. Lavatory Waste Plug

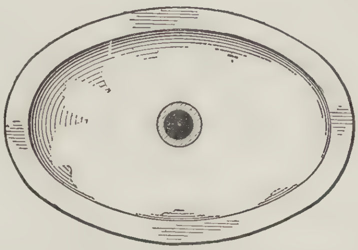


Fig. 179. Oval Bowl—Section of Minor and Major Axis

Fig. 178. Plan of Common Oval Bowl

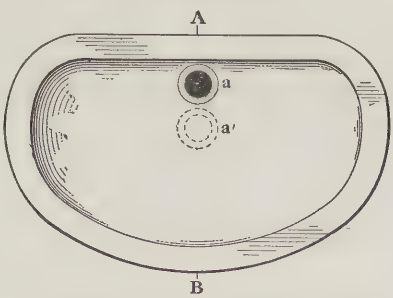
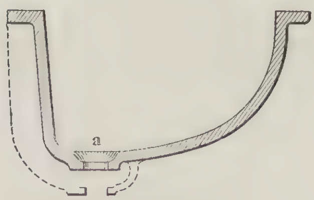


Fig. 180. Plan of D-Shape Bowl D-shape Bowl



Section on line A-B of Fig.180

Fig. 181. Cross-section of D-shape Bowl

in Fig. 181, it has no equal, for the faucets can then be turned out of the way to the very margin of the bowl area. When its slab is recessed in front, as in Fig. 182, the fixture is most convenient for hair shampooing,—so much superior to other shapes in fact that most hair dressing establishments have adopted this form of lavatory.

While bowls and slabs were more generally of separate parts, there

was never a complaint about ricochetting water. This was because the bowls were larger than the holes to which they were fitted, as shown at **Z**, Fig. 185. The abrupt ledge reflected the water back into the bowl. With the advent of iron and porcelain lavatories with bowls made integral, came loud and frequent complaint. The bowl and slab surface was continuous and unbroken, presenting nothing to check the course of the water, as shown in Fig. 183. The D-bowl plays an important part in neutralizing this evil by presenting a comparatively flat surface under the faucet nozzles. For other forms of bowls, for use with high pressures, the pressure water-ways of faucets have been reduced, nozzle areas increased, or chambers added to the bodies, all with a view to reducing the velocity of the flow from the nozzle for the purpose of minimizing the splash. A stream controller placed in the end of the nozzle also causes the water to flow gently.

Stream controllers are merely ribbons of thin sheet metal formed up in a way to honeycomb the nozzle area with sufficient aligned frictional and capillary surface to give the water a quiet unswirling common direction in the form of a solid stream much resembling oil in its action.

There has been considerable trouble with iron lavatory faucet holes. The slab is thin and generally without bosses or holes extensions. The squares made on faucet shanks to keep the faucets from turning in the hole project below the slab when there is no extension, and if a square extension is cast on, the direction of the faucet nozzle is thereby unalterably fixed on any form of faucet that does not separate in the body above the slab and below the nozzle. When solid body faucets are used on marble or porcelain, there is a chance to change the direction of the nozzle by recutting the faces of the square to a different angle and bushing the hole if necessary. Also, the square counter sink of faucet holes in marble can be ordered cut at any angle desired, or, ordered to be left uncut, thus giving the plumber a chance to cut them to suit, on the job. Iron lavatories leave no chance to alter the hole for the better. Bosses, a feature not so essential, have been abandoned almost entirely and some fixed method of providing for the faucet squares has been adopted by each maker. The best one of the faucet setting plans is shown in Fig. 184. The hole in the lavatory slab is round and large enough to admit any square. On the bottom of the slab on opposite sides of the hole, two plugs or pins are cast like **X** in the sectional sketch; to hold the square of the faucet a separate piece is provided, being a square nipple, with a square hole in it for the faucet and having a flange with a cogged circumference cast on it; by setting the flange of the piece against the slab centered over the faucet hole, two of the cog notches fit over the two pins on the slab as indicated at **X′** in the perspective sketch. There are 6 pairs of cog notches on the flange. This permits pointing the faucet nozzle to within $7\frac{1}{2}$ deg. of any direction desired,

by changing the adjustment of the keeper-piece, which of course carries the faucet square with it. The faucet square does not reach to the bottom of the keeper-piece, so a wrought washer can be slipped over the shank and the faucet lock-nutted down in putty in a fairly satisfactory

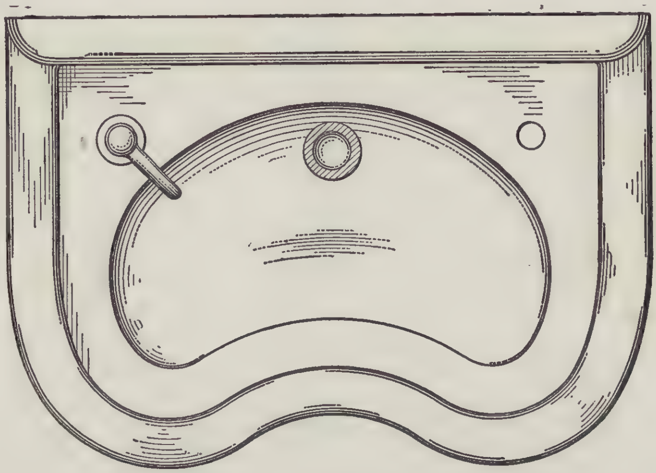


FIG. 182. PLAN OF LAVATORY WITH CRESCENT BOWL AND RECESSED FRONT

manner with the nozzle pointing at least approximately in the direction desired.

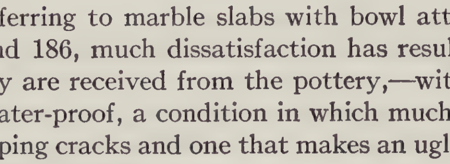


FIG. 183. FORM OF BOWL FAVORING RICOCHETTING

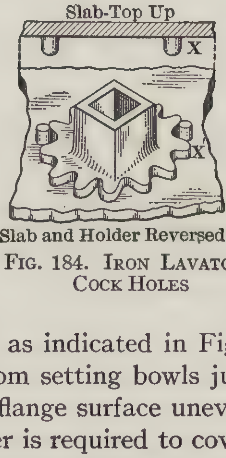


FIG. 184. IRON LAVATORY COCK HOLES

Referring to marble slabs with bowl attached, as indicated in Figs. 185 and 186, much dissatisfaction has resulted from setting bowls just as they are received from the pottery,—with the flange surface uneven and water-proof, a condition in which much plaster is required to cover the gaping cracks and one that makes an ugly job, unreliable because the plaster will not hold.

In Fig. 186, **F** represents the unground edge of an earthenware bowl, and **G** the flange face after grinding down the high parts until a full flat ground face without glaze is obtained. Every marble works is prepared to do this while you wait, it being only necessary to hold the bowl on the large horizontal revolving disc used to grind slabs to a plane, where sand, floated by water between the bowl and metal disc will cut

away the whole flange in a short time. When a bowl is thus ground, its flange saturated with water and the marble wet, a 14×17-in. bowl can be set with a heaping tablespoonful of plaster. The plaster must be made thin, placed on the marble inside the bowl flange mark and the bowl held just where it is wanted before lowering it to the slab, because suction will make it difficult to move it at all the moment the bowl touches the plaster.

There is a difference of opinion as to whether an overflow should be turned to the front or to the back,—when the holes are at the front they are not always seen, and are sometimes forgotten when they should be cleansed; when at the back they are always in plain view of the user, and thus detract from the good appearance of the stand, but are most certain to be kept clean. **H**, in the upper sketch of Fig. 186 is the slab; **J**, the apron; **K**, an angle attaching the apron and **E**, the point of a bracket on the opposite side of the bowl. Any marble lavatory looks better with an apron, even though it is supported by brackets instead of by legs, which are usual with aprons. If corner pockets are not used the front apron should cross the end pieces. Wall pockets made a good finish and should always be used though they are not essential. Corner pockets as a feature of legs for aprons are in keeping with the leg design, but suitable corner pockets alone are not always obtainable without delay, and sometimes not at reasonable cost. A very neat job can be done, if necessary, with common brass angles alone, concealed as at **K**, placing one on the apron pieces near the bottom at each corner, to keep the ends from becoming uneven.

The early types of enameled iron lavatories were made with separate back and required the support of separate brackets, leg-brackets or legs and frame with wall attachment, much as do marble goods. Most of the later lavatories and many patterns of sinks with back are now cast in one piece. The wall edge of the back except between the ends at the slab level is in one plane, with a short flange turning inward, as indicated at the top in Fig. 187. This gives sufficient bearing surface to permit the fixture to hang on a lathed wall as a bracket without danger of the heels of the back cutting into the plaster. One-piece construction was soon followed by a plan for very generally dispensing with the separate visible bottom brackets which are frequently in the way of pipes and often difficult to secure a wall hold for without cleats, because the flange is narrow and the position fixed by ears on the slab. The bracketing feature was supplied by considering the fixture itself a bracket. Lugs tapering from front to back were added to the back flange, as at **a**. These fitted into corresponding pockets, **a** and **a′**, cast in the separate hanger-piece, **A**. Numerous screw holes are provided in **A** so as to be able to secure a hold in plugged brick joints regardless of where the joints happen to stand behind the hanger.

Being used in a level position, two studs are nearly always crossed by the hanger when used on stud walls. The whole space behind the lavatory back being covered, there is no need to mind the looks. If safe screw holds are not readily found, the plaster can be cut away and a cross-piece set in, from stud to stud, projecting from one stud, or from joint to joint, according to the wall. The points **Z** under the

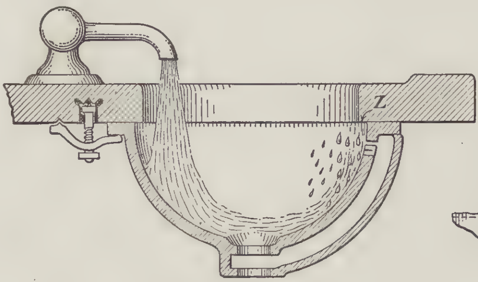


Fig. 185. One Form of Lavatory that Prevents Ricochetting

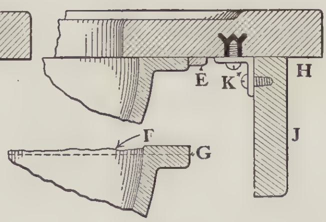


Fig. 186. Marble Aprons and Ground-face Bowls

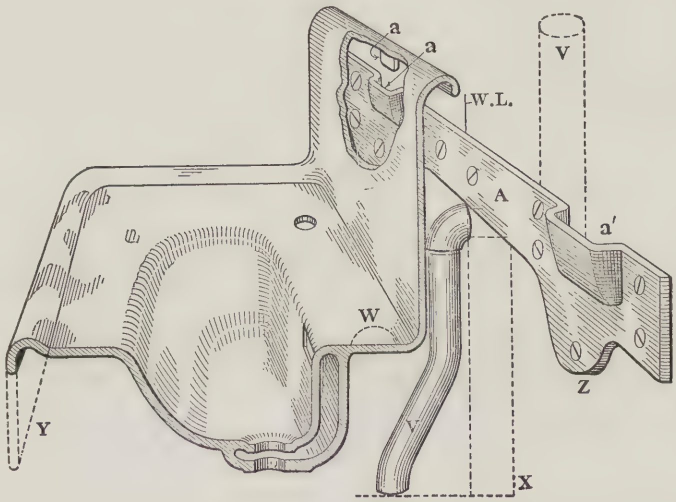


Fig. 187. Bracketless Iron Lavatory with Bowl Shaped to Prevent Ricochetting

pockets on the hanger are to resist the torsional strain due to the out pull of the lavatory. The inward thrust of the weight at the heels of the back flange is in part resisted by a concealed flange extension or ear, as at **X**,—the dotted lines, though not so aligned, are to be taken as the wall line,—line of the lavatory back wall and bottom line of edge or skirting. A wood screw through these lugs into the wall, one at each side, keeps the lavatory in place. Without them the fixture, when not connected to the pipes, can be instantly lifted from the wall. When

placing a lavatory on the hanger the taper faces of the lugs and pockets draw the flange tight to the wall as it settles into place.

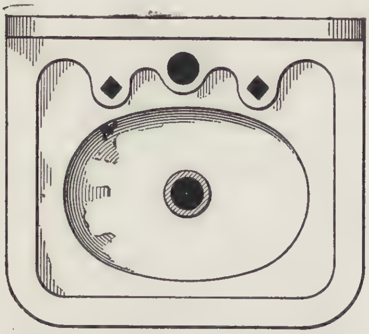


Fig. 188. Marble Slab with Semi-bosses Projecting Into the Countersink

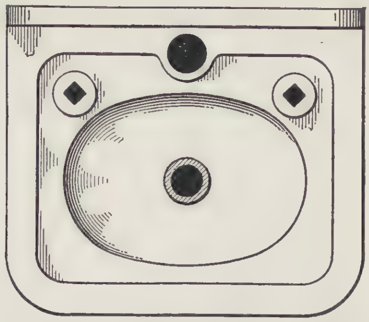


Fig. 189. Marble Slab with Faucet Bosses Countersunk all Around

The space between the back of an iron lavatory and the wall offers an easy means of carrying the vent of the trap, comparatively upright, to above the level of the bowl, if desired, as shown by **V**, Fig. 187,—**W-L** being the wall line.

Fig. 187 gives a good idea of the shape of a D-bowl. Dotted lines **Y** indicate apron depth, the part in solid line extending only to the usual depth of the roll edge of a common lavatory. The overflow pocket is

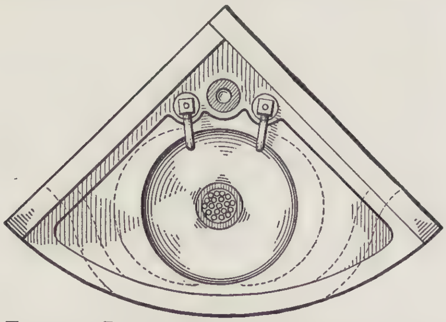


Fig. 190. Round and Oval Bowl Iron and Marble Lavatories

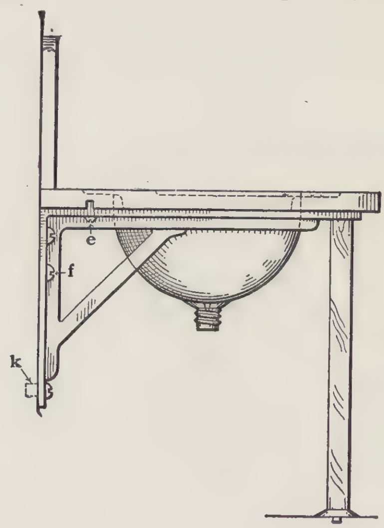


Fig. 191. Bracket and Bracket-Leg Support

indicated,—a nickel-plated brass grating with chain stay ring, bolted to the back wall of the channel is usual for patent overflow bowls. If the slab is for a standing waste and overflow, no channel is necessary, and the standing waste hole is placed at **W**. Patent waste stoppers designed to do away with loose stopper and chain are generally operated

by a rod or "lift" placed in the overflow channel, the knob projecting through a hole from the channel in the face of the slab which sometimes also contains the overflow grating.

It was stated in connection with iron lavatories, that faucet bosses are not important. This is true with iron lavatories, first, because the faucets stand inside of a general continuous countersink which forces stuffing box leakage or other slab water to flow into the bowl; second, on any material not easily stained, the plumber is always prepared to set a faucet water-tight. With marble or onyx, however, the plumber does not care to bed a faucet in plaster if he can avoid it (too much trouble and risk follows, if the faucet has to be taken out) and as oil stains, putty is not suitable. Therefore with these materials it is best not to place a faucet in a general countersink without a boss, as is regularly done with iron fixtures. To cut the bosses projecting into the countersink, as shown in Fig. 188, is no better, for the water is thus just as likely to find its way to the floor, especially if the slab is slightly out of level in a way to favor it. The proper way is to leave the bosses standing free *within* the countersink, as shown in Fig. 189. The standing waste is not a source of water so it is immaterial whether its boss stands free or not,—being above the countersink, leakage cannot reach it when faucet bosses are cut free of the high border.

Marble corner lavatories are always lacking in room at the back, especially so, as may be noted from Fig. 190, when a standing waste is used. The faucet nozzles stick out into the bowl space in the way of the head when leaving the face, and the bowl, generally round, is small. In the iron patterns, swell fronts have been made, as indicated by the dotted lines, favoring the use of oval bowls; these, with a bowl with straight down back wall, offer a chance to spread the nozzles to the utmost so as to leave the bowl area comparatively free together with slab room to reach back to a waste "lift." A corner fixture does not need legs or brackets,—cleats or angles screwed to the side walls answer better. Iron corner fixtures are hung on the same principle as illustrated with the flat back in Fig. 187. When placed on marble walls, the slab corner is often covered over by using a three-piece back,—a triangular piece covering the pocket at the top of the back in a way to make a convenient shelf. Sometimes the plan is carried a little further by bringing the pipes up close in the corner and through a narrow slab set across the corner at an angle of 45 deg. This makes an octagon corner under the slab and conceals the pipes in a space easy to reach and safer from the elements than when behind a permanent wall. The octagon corner piece is set over two floor dowels and anchored to the slab, at the top, by a screw through a metal angle, or by a screw leaded into the side wall high up, out of ordinary view.

Leg supported lavatories need other anchoring to support the slab

at the back and to keep it from wobbling. Metal aprons are stiff but are rarely used and marble aprons do not meet the requirements. All that can be expected of marble aprons, aside from appearance, is to give continuous support between points, for *they* require anchoring and support from the slab, legs and wall, or all combined. When aprons are not used with legs a bracket is ordinarily added to the leg making it a bracket-leg or leg-bracket. These, like shown in Fig. 191, are used for three reasons,—when the slab is heavy and the brackets short of or a character making auxiliary support necessary; when short wall faces are desired to avoid conflict with pipes, and, when legs are to be a feature where bracket aid is the most natural means of supplying the other support needed. Sometimes the point of the bracket has a hole through which a dowel from the leg passes on into the slab, thus loosely tying all three together at that point. In other cases the leg attaches to the bracket by means of a countersunk screw passing down through the bracket into the leg, and the slab is held by a dowel projecting into it from the bracket or by a screw through the bracket flange as indicated at **e**,—the latter plan is best as it holds the slab in place both ways. If the factory made holes in a bracket are too small or more of them are needed because of the size screw that can be used, or the kind of fastening they go into, the plumber should not hesitate to drill additional holes, as indicated at **F**. If for any reason, the strain on a bracket will be great, and the wall is soft, such as an ordinary lathed and plastered surface, it is best to make a hole in the plaster behind the bracket point and set in a chunk of wood, scrap of pipe or other material, as shown at **k**, that will not compress, so the bracket will not gradually cut into the wall finish, which would not only mar the wall but lets the slab down.

The author has erected several marble and onyx lavatories, with backs, and without backs, without the use of factory made brackets or legs. The plan, illustrated in the sketches of Fig. 192 is one that makes a good job, free of floor support, practically without visible wall support, suitable for stud walls with any kind of facing, but not adapted to fireproof block partitions. It requires special preparation in the way of wall attachment, for brick walls. In the main sketch a $1\frac{1}{2}$-in. angle iron bent to a right angle is shown screwed to the stud behind the plastering. Two of these will hold up any single bowl slab,—three, any two-bowl slab, etc. It is best to locate the position required for the angles before the plastering is done and to set in and anchor pieces of studding, if necessary, and screw on the angles just as though going to put up the slab immediately. The question of support is then settled and if well done a leveling screw for the slab will not be needed. If a leveling screw is used, tap a hold at the point of the angle, so as to be able to raise the front,—the wall edge will never sag. If no other screw anchors

the slab, one should be placed at **S**, in each angle. Apron pieces can be attached to the slab if desired.

If it is desired to set the angles after the plastering is done, their wood holdings can be located, as usual, before the lathing is on and a notation of their positions kept. The screw holes for attaching are then made in the other (front) face or leaf of the angle, and in bending, the angle is cut in the projecting leaf, bent short, and a piece of web welded in to fill the gap. When the time comes to screw the angles in place, the lath and plaster is cut away to bare the face of the wood to be screwed to, and the angle set in with the screw holes against the face and the other leaf projecting inward and up and down along and against the side of the piece to be screwed to.

If the wall is to be marble faced this plan simply makes a job of cutting two holes or places the shape of the angle in order to slip the marble into place while these parts are projecting.

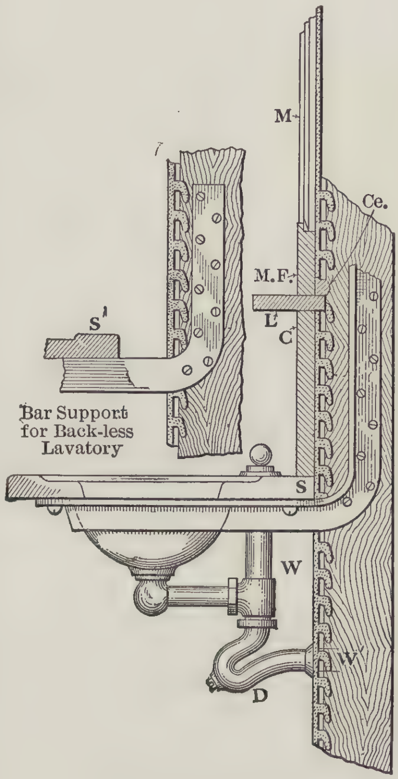


FIG. 192. MARBLE SLAB WITH CONCEALED SUPPORT

When the wall is brick, wood blocks for the angles can be securely anchored in the right position when the wall is being built, and angles made and set like those last described. When such fastenings are anchored in place, a strip of wood should be set on the web side of the block so it will be easy to make space for the web that sticks inward by removing the strip when ready to put up the angle. One good way to anchor blocks in brick walls for this purpose is to fit through them, two rods or pieces of $\frac{3}{4}$-in. or 1-in. pipe 4 or 5 ft. long. Close fitting holes, about 2 ft. apart, bored so the two pipes will answer for both blocks and so stand with the wall and back of the first or second course of brick, according to thickness of wall, will answer.

If a backless slab is to stand free of the wall, plain $\frac{1}{2}\times1\frac{1}{2}$-in. or $\frac{1}{2}\times2$-in. bars may be bent and used as shown under **S′**, Fig. 192, or the angles may be used as last stated and a portion or all of the exposed flat web cut off so as not to show a wide bar back of the slab. The ex-

posed portion of angles can be bronzed or nickel-plated. In Fig. 192, **S** is the slab; **W**, standing waste and overflow; **W′**, waste in wall; **D**, lavatory trap; **C**, lavatory back; **L**, shelf over back; **ce**, cement filling between plaster and shelf, with perhaps a nail at stud to hold shelf down at back; **M.F.** bottom piece of marble mirror frame and **M**, the mirror.

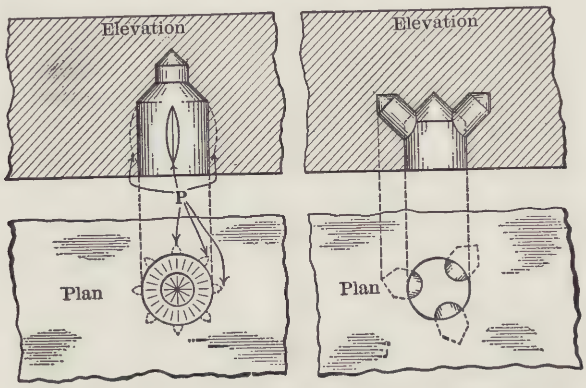


Fig. 193. Details of Anchor Screws and Bolt Holes

Anchor holes for bowl bolts and slab screws are shown in plan and elevation in Fig. 193, the usual and better plan for bolts being shown at the right and which consists of drilling first somewhat larger than the bolt head and then, at the beginning of the point sump, with a smaller drill, making three or four equally spaced holes $\frac{1}{4}$-in. deep or more at as great an angle as the large hole will permit. For screws, a $\frac{1}{4}$-in. hole is drilled as deep as desired; the small hole is then reamed down to the depth desired for the lead and the large hole ditched as indicated by **q**, or the whole wall of the hole bellied out into barrel shape of about the contour indicated by the dotted lines in the elevation. The latter plan gives the strongest hold, but the former insures that the lead will not turn in the hole instead of leading the screw into place. The size drills used depends upon the sizes of screws and bolts,—$\frac{1}{4}$-in. and $\frac{7}{16}$-in. drills answer for the screws and bolts ordinarily used on lavatory work.

CHAPTER LIV

Sinks and Fittings

A great variety of sinks are made for kitchen and pantry use,—in copper and german silver lined for fine pantry service and in enameled cast iron, galvanized pressed steel, porcelain, slate and marble for residence kitchen and pantry service. Slate is less used than formerly; marble sinks are now and then fashioned from a solid block; porcelain is liberally used, especially in the more expensive grades of work; steel is used on some ordinary work; enameled cast sinks are much used in all grades of buildings; wood sinks are confined to hotels and institutions where heavy table ware is carried in baskets and dumped about in bulk lots.

Lined and simple wood sinks are easiest on fine china. Only lined sinks—planished, nickeled or copper, or german silver are fit for fine residence work. Aside from lined sinks, other kinds for pantry use do not differ from kitchen sinks, except in being of smaller size and generally plugged to use as a vessel. Otherwise the difference is in the fitting,—high goose-neck faucets suitable for rinsing being regular for pantry service.

No form of sink will ever be ideal for residence kitchen use. If small enough to use as a vessel they are not fit for general service and are too cramped to set a bucket in to draw water; if large enough to set a dish-pan in they are too large to be used as retaining vessels for washing articles, and generally also out of proportion to the room.

The faucets should be high enough to place a water bucket under; the waste should be $1\frac{1}{2}$ or 2 in. diameter, according to size of sink; the drain-board should have at least 1-in. fall and stand free at the back unless the sink back extends behind the drain; if a back other than factory made is to be fitted, it should be rebated over and down into the sink, stand away from the wall on cleats so air can circulate behind, extend to the end of the drain and be not less than 12 in. high. Polished marble is the first choice of material for a back, slate the second, and oiled hardwood—oak, cherry or black walnut—third.

There appears, from experiments made by the author, to be no practical difference in the time required to cool a body of water 10 deg. when drawn at the same temperature into enameled iron and "solid porcelain" sinks of the same size in rooms of the same temperature.

Earthenware and slab sinks are invariably set on legs and brackets, leg-brackets or leg-frames, because of their considerable weight. Legs are regularly furnished for the heavier enameled kitchen sinks and on

the larger sizes some makers refuse to furnish them without legs because many plumbers have been careless about the stability of their work. With the one-piece sinks with back or back and drain cast on there is little to do but fasten them up and connect the pipes, small sizes being hanger-set like lavatories; but, with the many other sizes and designs and the variety of conditions encountered in routine work the workman has a chance to exercise all his skill, for the work must be in keeping with the surroundings, and in all cases the primary consideration is to produce, if possible, a reliable job permanent as to stability, satisfactory as to convenience and as sanitary as can be made considering every element affecting the installation.

The general run of common sinks are made 6 in. deep, with end outlet like shown in No. 1 sketch, Fig. 195, in which **a** is the flat rim or flange; **d**^{2}, screw hole in wall side flange for securing to cleat or wall angle; **d**, **d**^{1}, holes for bracket or bracket and drain; **O**, overflow holes, and **P**, plug strainer. Common sinks are seldom fitted with plug strainer; when so fitted the sink should have an overflow,—regularly cast on and joining the waste outlet as in a P. O. basin bowl. All rim holes, whether for back fastening, brackets, drain or legs, are drilled by the plumber. To drill enameled sinks, invert them, let the hole location rest on solid wood and drill through from the iron side. An extra grade of common sink is made with "half-round" flange like in small sketch **a**^{1},—in these the corner and bottom angles have considerable radius and some patterns have a center outlet. The common sinks have square inside corners. No. 2 sketch, Fig. 195, shows a center outlet roll rim form,—center outlets drain cleaner; **d**^{4}, dotted, indicates the line of contact of the loose enameled back used with such sinks; the sink edge of back has a lip extending down below the flange level to drip splash water back into the sink; **d**^{3} is a cleat or bracket hole. The back may be bolted to the sink through holes or gaps; roll rim sinks have deep backs that take in cast air chambers; only shallow pattern backs are furnished with common sinks.

In the two-bolt outlet shown at **P**, two nuts are used on each of 2 long bolts threaded up to the head,—two with washers over the nuts make tight against the sink wall to keep water from running out of the sink; the other two, preferably brass on brass bolts, are to catch on the lugs of the pipe collar to draw it up against the sink nipple. In 4-bolt outlets two long bolts, shown at **c**^{1}, No. 5, and dotted at **c**^{1}, No. 2, are put in before the strainer, and made tight,—two extra nuts on these, grip the collar; two shorter bolts, **c**, Nos. 2 and 4, then pass through the strainer and sink wall to alone fasten the strainer in place. This is an advantage in that the strainer can be renewed without disturbing the pipe. Only brass bolts should be used on strainers. All sink strainers

should be brass. The sink collar is slipped over the waste pipe which being then flanged out in the collar is drawn up with putty between the pipe and sink nipple. The pipe c^3, collar c^2, sink outlet and strainer are shown suspended one above the other in sketches 4, 5 and 6, Fig. 195. **c** and c^1, sketches 4 and 5, correspond to **c** and c^1 in sketch 2. Collars with iron pipe thread for connecting iron waste direct to the sink are made.

Sketch 3, Fig. 195, is an improved method of connecting sink pipes. The spud, of which the prongs are forced to show in the drawing, and the lock-nut furnish a threaded nipple for attaching by collar and gasket, a tail-piece soldered to the pipe, making the connection as solid as a closet flush-pipe or wash-stand coupling. The strainer is cupped and perforated on the edge and bolts down to a bridge bar.

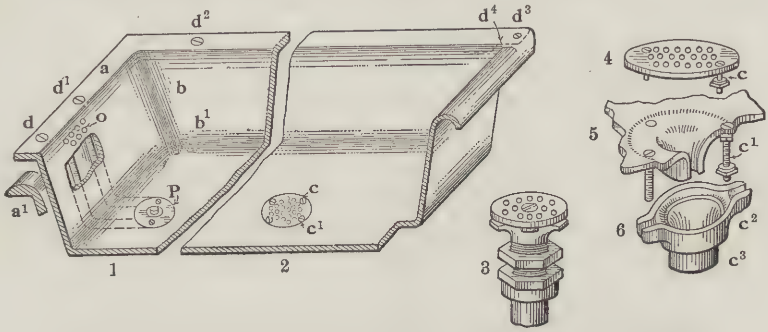


Fig. 195. Kitchen and Pantry Sink—Their Rims and Outlets

In Fig. 196, No. 7 shows the use of angles or short brackets for supporting flat flange sinks free of the wall at the rear; **A** is an angle; **B**, the sink; **C**, bolt binding sink to angle; **D**, wood cleat for holding sink-back; **E**, screw attaching cleat to wall; **D**, loose dowel holding sink back in line at bottom; **G**, a small anchor screw leaded to back and attached to cleat,—used near top of back when it is desired not to show screws in the face of the back; **P**, supply pipe passing up to faucet between angles, sink, wall and cleats. If dowels, **F**, are wanted fixed, tap the hole in the flange, screw in a short bolt and saw off the head. No. 8 shows sink attached to bracket at rear. **H**, is the shelf brace-web; **L**, shelf flange; **I**, bolt to hold down and back to wall the sink back; **J**, hook bolt binding flange of sink to brace-web of bracket,—it passes through shelf flange unless flange is broken out for it; **K**, supporting flange of sink back; **M**, the sink back. The flange **K** and sink flange must be sawed out for the supply pipe if it rises from the floor, and for bolt **J**,—some makers see to the former before shipping. When the sink is a flat rim, the slotted shelf face of a regular sink bracket permits fastening the sink with plain bolts further out, if holes in the rim and screw heads showing are not objectionable in case they would not be covered by

drain ends. A slotted bracket leaf does not always work as well in roll rims as a plain vertical web like **H.**

In Fig. 197, No. 9 sketch shows some ordinary means of securing and flashing common square kitchen sinks at the wall side. If a splash-back **T**, with cap **U**, is used, **N** may be considered the wall; if back cap flashing like **O** is used over the sink flange, then **N** is the splash board fastened to the wall and to which are secured cleats **R** and **S**,—cleat **S** setting below the level of **R** far enough to equal the thickness of the sink flange, so the cap flashing **O** will have a flat bearing. If a splash back, vertical from the sink flange, like **T**, is used, it makes no difference about the leveling of **R** except so far as it contributes to holding the sink in the proper place. **Q** is the sink wall under the cap flashing; **Q′** indicates the same dotted under a splash back; **V** points the cleats extending to the top of back for holding back and back cap. Double cleating gives room for the pipe to pass up when the splash is in front of the supply. If desired, the sink flange may be cut out for the supply when the splash is behind the pipe,—some puttying behind the pipe at the flashing gap is always necessary when the pipe is over the back board.

No. 10, Fig. 197, indicates a home-made drain board attached to a flat rim sink. **W**, is the sink end; **X**, the bracket flange, with screw passing up through bracket and sink flange into the drain,—if this is not done the drain cleat **Z**, must be rabbeted more or less as shown to fit over the flange of sink; so doing increases the power of the cleat to hold the drain flat and keeps it bearing on the sink. The drip bead at the end of the drain, **Y**, is to prevent water seeping back between sink flange and board. Two cleats belong to a board, the one on the out end generally standing on the supporting brackets.

A home-made wood drain can be easily fastened to a roll rim sink by a bolt passing through an angle, placed on the board, and near the edge of the roll rim, but iron drains depend upon provisions made by the makers. One method is shown by No. 11, Fig. 197, in which **a** is the sink, **b** the drain end; **C**, doves cast on bottom of board, and **d** a keeper bolted to the doves,—that this arrangement prevents movement in any direction is evident.

In No. 12, Fig. 197, the attachment of cast legs to roll rim sinks is illustrated. The leg fits over a guide ring cast on the bottom of the sink, as dotted; two lugs, diametrically opposite, on the legs, bolt to corresponding lugs or ears cast to match, on the sink.

If legs are used with flat rim sinks they are, as shown in No. 13, either cast legs fitted into doves cast on the side wall (**S**) of the sink, or they are plain gas pipe with a screw leaded into the upper end. The screw runs down into the leg through the sink flange, the pipe being flattened slightly to keep the lead from turning. A flange or waste nut is used at

the bottom of the leg. Wood capping is often put around the top of common sinks, as indicated by the dotted line over **S** in sketch No. 13.

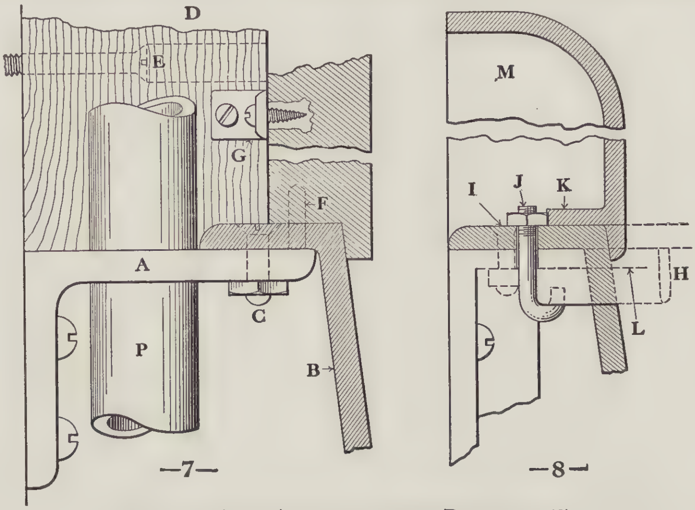


Fig. 196. Sink Angles (7); and Brackets (8)

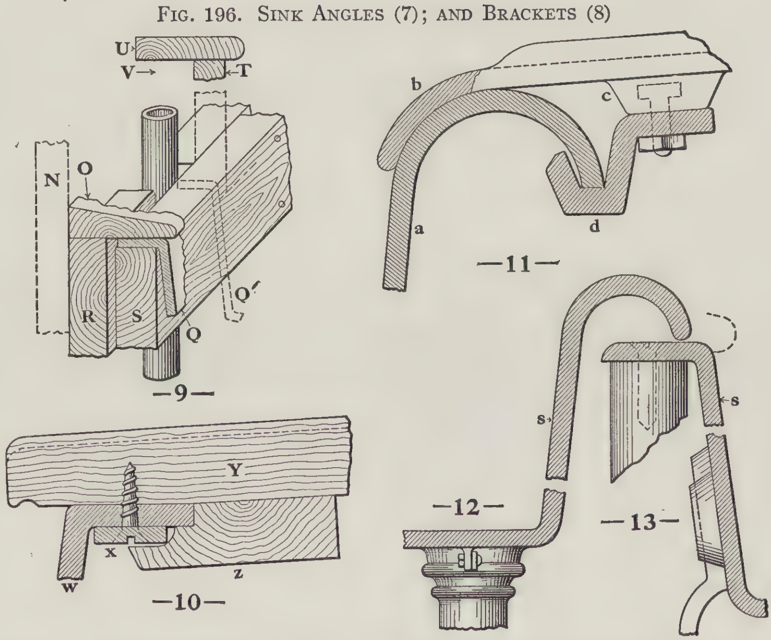


Fig. 197. Sink Cleats, (9); Legs, (12 and 13); Drain Boards, (10 and 11); and Backs, (N and T), Sketch 9

Grease Traps

Though not a regular feature, grease traps are frequently used on kitchen sink wastes to separate the grease. The grease, in itself, is not worth the trouble in residence work but keeping it out of pipe saves the

expense of waste pipe cleaning which follows in time from grease choking the pipe if not kept out. The proper location for the trap is close to the sink. Two means of separating the grease are practiced; both are applicable to any residence job; in either, one trap serves for both grease separation and sewer air protection; both depend upon the specific gravity of grease being less than that of water,—one type of trap employes means of flotation only; the other, more effectual, combines chilling of the grease with the principle of flotation.

Fig. 198, in the solid lines represents the type of trap that employs flotation only. In it, the waste drops in direct from the sink, as seen on the right; the inverted return at the left is the waste outlet; **V**, the vent; **G**, a rubber ring gasket to make tight the loose cover, and **H**, swivel clamp-screws hinged to the body and used to secure the cover. Water stands in the body at the level of the neck of the outlet bend; a partition extending up from the bottom divides the body for about three-fourths of the water depth,—this partition deflects the waste and grease upward; the grease floats to the surface as the waste passes over the partition. The accumulations on the surface in the body are skimmed off as necessary.

By considering the dotted wall in Fig. 198, as a cold water chilling jacket operated by passing through it the cold water storage tank supply (which is ultimately to be warmed anyway),—entering it at **I** and issuing from **D**, the essentials of a chilling grease trap will be seen in the sketch. The flotation trap is usually a cast body enameled inside, (sometimes also enameled outside) with brass trimmings; it may be had with hub openings for soil pipe waste. The market form of chilling trap is usually a jacketed brass cylinder. The jacket takes the supply on one side at the bottom and delivers it at the top on the other. The inner or waste cylinder has a removable top; some forms are provided with a wire cage, with bale, which lifts all the grease as it is pulled out of the trap.

Slop Sinks

No plumbing job is complete without a slop sink. The kitchen sink and closet are not proper places for all manner of scrub and waste water, and if they were, are not always accessible; besides, much carrying up and down results from such use. No other fixture, except the sink and trays provide certain means of drawing water in buckets. The slop sink may be a wide, deep, common square sink on legs with 2-in. or 3-in. outlet pipe, trap and waste, and fitted with plain hot and cold faucets over it, or it may be an elaborate porcelain or enameled iron sink, say 16×20-in., 12 in., deep, on pedestal-trap, and with plain roll rim or with integral or cast brass flushing rim supplied by a high tank with flushing pipe and pull valve, and fitted for drawing by a

combination cock with extended nozzle, bucket hook and nozzle brace, all having about the general appearance seen in Fig. 199. The left side of the sink shows the solid porcelain form with roll edge, **S**,—also made in flushing rim style; the right half shows the enameled iron form with attached flushing rim, **F**, which may be of brass or enameled iron. The pedestal-trap has interior weirs, as shown,—is vented, and fitted with a cleanout screw. Open wall cast pedestal traps are also made for slop sinks. With the pail support nozzle it is not necessary to set a bucket in the sink.

Wash Trays

A set of trays may be two or more, usually three,—one to rub in, one for the second rinsing suds and one for final rinsing or blueing water. A means of attaching the

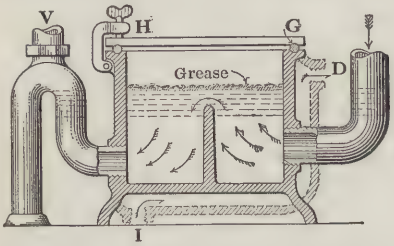


FIG. 198. FLOTATION GREASE TRAP—CHILLING-JACKET PRINCIPLE

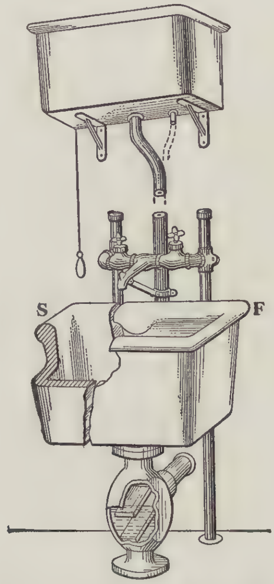


FIG. 199. SLOP SINKS AND FITTINGS

wringer is essential. Tubs were supplied, one to each set, with a wash-board surface, like sketch **W** in Fig. 200, but the front wall of all makes is too nearly perpendicular to answer successfully for rubbing surface. The height of top edge of trays should be about 30 in.,—if too high a foot bench can be used, but if too low for the laundress, there is no quick cheap remedy. Wash trays or tubs are made in enameled iron, porcelain, slate, soap stone, composition, and wood,—the wood trays being now all but confined to institution work. Porcelain and enameled iron are the most used. The iron kind is mostly supported by a center pedestal as at S, Fig. 200, and, porcelain and slab goods by a frame with legs like **L** in the sketch. Wood wringer attachments are bolted to iron rims as at **A**; any wringer that will fit a good hand tub, or wood wash tray wall will fasten to it. On porcelain goods the feet of the wringer must be adapted to clamping the rim. Sink and tray *combinations* are made for flat work, the sink drain answering as a tray cover when the sink is in use.

If flat rim trays with wood frame and cover are used, the wringer problem is solved for both iron and porcelain trays and the cover answers

for a splash back. With cover so used the cocks must be in the tray wall as indicated at **X**[1], the holes being at the same or different levels, according to the scheme of piping. The better way is to provide a splash back, as is done by the maker for iron trays, and place the faucets on it. The pipes may be either before or behind the back according to local conditions. Long enameled backs, and roll rim trays are joined by means of nickel-plated union-strips like indicated in section at **U**, the bolts passing through the web and through ears or flanges on the tubs.

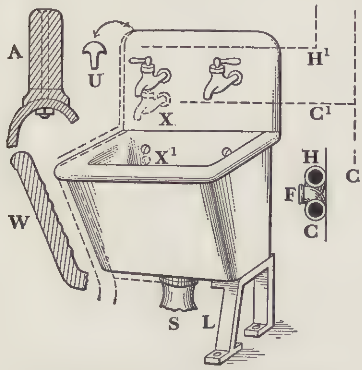


Fig. 200. Wash Tray Features

When cocks are used in the trays the side handle pattern is best, using the right-side handle on the left side of the tray. Top handles are either so low as to court leakage at the holes, or the handles project too high for a cover; end handles stick too far into the tub. The cocks may be placed at different levels (**X**) when the supplies are on the face of the back or behind a home-made back, but one cock is too low if **X**[1] position is used for one supply. There is but one way to put all the cocks in line without crossing the main pipes,—that is, as shown dotted in the sketch, **C**[1] being the cold supply and **H**[1] the hot water pipe. Wash tray supply fittings are made for the purpose, as seen in the small sketch at the right in Fig. 200, and may be used above or below the top of the trays. **F** is the cock opening and **C** the "run" of the lower pipe fitting and **H** the "run" of the upper pipe,—these save common fittings and bring the lines near together.

Overflows are made in any form of trays, if ordered. One trap is sufficient for a residence set. Brass $1\frac{1}{2}$ in. waste, with plugs and couplings of the same type as used on lavatories is usual. For lead waste on wood trays the size is $1\frac{1}{2}$ in. or 2 in. according to the number of trays. The branch pipes are fitted with blind flanges screwed to the bottom of the trays; the lead waste extends above the blind flanges enough to flange into a counter-sink in the wood, and a brass frame for the stopper is screwed down in putty, over it, with brass screws.

CHAPTER LV

Water Closets and Fittings

The water closet is not only as great a convenience as any but is the most important of plumbing fixtures. Without it plumbing would be minus the need of knowledge contributing most toward lending the dignity of a profession to the foremost of mechanical trades, for no appointment, not even the soil-pipe, essential to safe dealing with soil would be necessary.

There has been some effort to introduce 3-in. soil pipe for closets and it is well to say here that it is to be hoped that 4-in. will continue to be the standard for an individual closet. There must be some margin, as there now is, between the diameter of the closet outlet and that of the soil pipe in order that the soil pipe will be certain to clear itself of whatever the closet introduces. With a 3-in. soil pipe, this still necessary margin would further reduce the closet outlet and thus court frequent trouble with the bowl; if clearance margin is not provided, the trouble from stoppages in stacks, a more serious matter as to cost, would follow. It is true that a 4-in. stack will do for many closets, but if the closet exceeds the stack capacity the same result may be expected as with, say a pair of scales,—weighing indefinitely within their capacity, they fail at once when it is exceeded.

A vertical 5-in. stack has answered for 100 closets taken in from numerous laterals; not less than an 8-in. or 10-in. should serve the same number taken into a horizontal run from their vertical drops.

Of the numberless designs in which closets have been made in the advance from primitive form to the present state of perfection little need be said. The numerous shapes and principles that accomplished nothing else so well as showing a chaotic state of the art have dwindled to the three general, acceptable, meritorious forms shown in Figs. 210 to 212, viz.: the washout, wash-down syphon, and jet syphon.

The pneumatic form withdrew sewer air from between two traps and expelled it into the room, through the bowl and was also expensive; it was therefore discarded. This objectionable feature of construction is present in pneumatic range closets, but is a minor evil where one tank action serves for a battery of seats. The range, however, is also destined to be discarded in favor of batteries of bowls flushed by one or more tanks.

The pan and plunger forms of closets were superseded because of their filthiness, though with them, flush and supply valves were brought to a high state of perfection,—a benefit which the trade will always

profit from by continued application, of the principles, as is being done with time valves in various ways on direct flushing devices now in use and with ball-cocks built on the principle of the old Jennings diaphragm valve.

Of the hopper closet variety, various closet hoppers, especially the tall valveless shapes, will continue to fill the need of something suitable for exposed locations where the outfit must be in itself proof against the action of frost. This is accomplished by a straight hopper of closet height, (about 15-in.) permitting the soil to drop to a trap frost protected by a pit or by earth of frost depth. The supply may come through a "pitless" frost-proof pull valve, like the street-washer in principle, or from a hopper valve set in a pit with the trap. In this way the pipe to the bowl drains back to below frost, and the swirl cleansing the hopper falling to the trap leaves nothing to frost action but a wet surface. Direct seat action gives continuous flow while the seat is held down. Indirect seat action requires an accumulating tank and a special form of valve which, when the seat is pressed, closes the way to the hopper and opens a passage to the tank in the pit; when the seat is released the supply is closed and a passage from the tank to the hopper is opened. Such tanks do not do well for exposed places when set above the hopper and either way, considerable water pressure is necessary. Such tanks (closed) depend upon the water pressure partly filling the tank while the seat is depressed. The pressure for flushing comes from expansion of the air thus compressed in the tank.

There are still in the market 1200 odd variations of hopper and trap closets made up of tall round and oval hoppers with and without seat action valves attached, and short round and oval hoppers for use on high or low pattern traps with or without seat action valves attached. These are all made with flush rim and with swirling rim; for valve flush and for tank flush; in black, painted and enameled, with similarly finished traps, vented and unvented. The trade is already better acquainted with these goods than it cares to be and therefore no detailed description is needed.

Of the regular forms for general use, the washout water closet bowl of the most used form is shown in Fig. 210. It is also made with the outlet leg at the back,—a form receiving more attention from the housekeeper because the outlet easily fouled in either form, is in the back drop-leg, in full view. Trapless forms offsetted to suit either front or back outlet "roughing in," for use with under-floor traps can be had. The bottom of the bowl dips so as to retain water to prevent soil sticking. Aside from the fouling drop-leg surface above the water, and the retention of more or less of the trap's contents in direct communication with the house, the washout has merit for residence use in that it allows examination of stools, a point of more or less importance in raising a

family of children. The usual flush rim scouring the whole of the bowl surface is provided. A sluice jetting an extra wash across the bowl toward the outlet leg is necessary to sweep the contents of the bowl into the trap. When a high tank is used (more of them *are* used with washouts than with other forms) the dribble from the long flush pipe insures the filling of the water bed. The flush pipe for a high tank washout and for wash-down syphons is of $1\frac{1}{4}$ in. diameter; for a low tank, the flush pipe is 2-in., as it is for all low tank service, on account of the low velocity due to a limited head.

The after-fill provided in all low tanks to re-establish the bowl water level for syphoning bowls assures a full water bed alone in the washout, though there is little danger of the flush-rim not doing so in any case. Washouts are easily vented from the bowl and are often so vented. The better way is the regular practice of venting from the upright below the floor, because no crown vent is necessary for a washout.

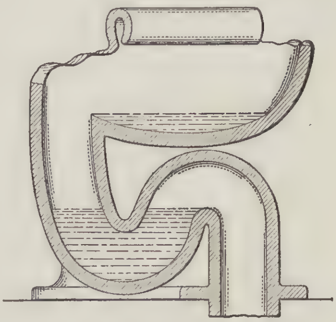


FIG. 210. SECTION OF FRONT OUTLET WASHOUT CLOSET

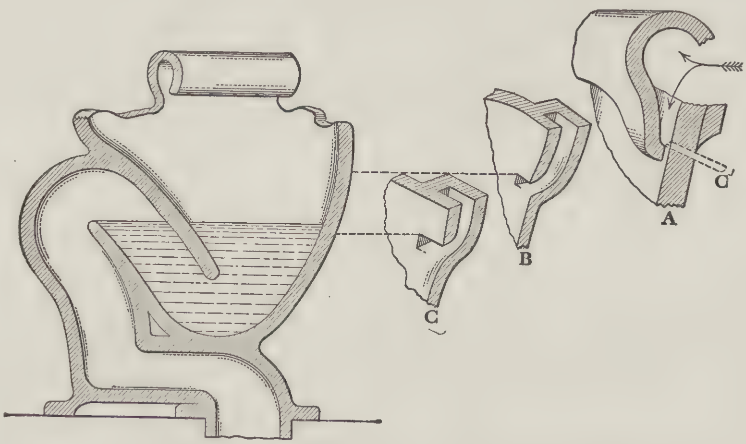


FIG. 211. COMBINED HOPPER AND TRAP CLOSET WITH DIFFERENT FORMS OF JET OR FAN WASH, CONVERTING IT INTO A "WASH-DOWN SYPHON" CLOSET

In Fig. 211 is a section of what is commonly known as a combined hopper and trap,—an integral combination of a flushing rim bowl with a trap. As shown, it is simply a hopper closet,—the bowl water surface, however, acts in place of the water-bed of the washout, but being eccentric to the flush rim (too far back) is not always effective. A heavy sluice wash down the front fairly cleanses the fouled surface. A fan-wash at the back as indicated by **C′**, sketch **A**, Fig. 211, is also usual. Instead of the fan-wash, some makes have a sluice low down, a little

above the water level, with the idea of wetting and quickly cutting down floating paper. The sluice is supplied by an outside channel from the spud, cast on the closet wall, as indicated by sketch **B**. This latter plan produced syphonic action of more or less strength and led some makers to submerge the sluice as indicated by **C**, in order to get true syphonage. True syphonage was usually to be so counted on, but the paper continued to float in the necessarily restricted bowl outlet, apparently leaving the contents of the trap unchanged. The submerged sluice was practically abandoned in favor of the sluice above but near the water level. The syphonage thus obtained is never as strong or full as in a jet-syphon closet, but it gave the name "wash-down Syphon" to the otherwise hopper and trap combination which would without the wash effect have been driven from the market.

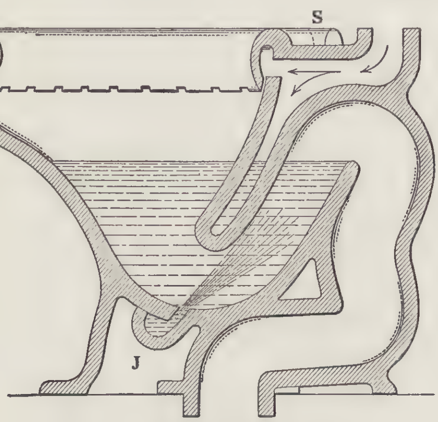


Fig. 212. Jet Syphon Closet

A jet syphon closet is shown partly in section in Fig. 212. This fixture is generally, aside from the diminutive bowl made for school use, full size, with liberal trap and water ways, though there are many shapes of bowl. Some of the flush water is diverted from the flush rim supply and carried down through a channel to the bottom of the trap, as at **J**, where it is injected in the direction of the common center of the trap up-leg. The flush rim water puts the bowl contents in motion; the jet adds its energy and increases the eduction velocity proportionally; water falling over into outleg is buffetted by the tortuous course shown in the sketch and thus breaks up more or less into foam and spray, helping to carry the entrapped air along with it,—all combined produces a strong syphonage completely exhausting the contents of the bowl and trap.

Quite a bit of water drops back in the bowl depression when the syphon breaks, and the after-fill of the tank raises the level of this to or near overflow. There is another form of jet syphon considerably used, depending on a spray jet operating in a rather large and less contorted outlet.

A high tank flush pipe for jet syphon closets should be $1\frac{1}{2}$-in. as they require more water to flush them and the period of action is too short to be well accomplished by $1\frac{1}{4}$-in.

Any of the three regular forms described can be had with local bowl vént nipple.

Enameled iron closets are made for mill and factory use and other locations where the service is especially severe. They also stand frost action far better than earthenware and there is no interior troubles like found in clay goods, but notwithstanding these good points, they have made little headway in the most ordinary residence work.

Seat lugs for carrying the seat directly attached to the bowl are now placed on all closets.

Seats so attached, by board cleats hold the seat firmly but the cleats cannot be kept dry and clean. Metal hinge posts are therefore more used. Where the bowl of the closet is far forward of the post holes, as in some forms of the jet syphon, either offset posts are used, or the connecting arms of the seat leaves are given extra length in order to reach the seat when it is in proper position. Offset posts are also needed in wash-down syphons when low tanks are used, in order to get the seat far enough forward so it will stand up.

Where the form of the trap is exposed, the base flange is given surface enough to make the bowl stable under the weight of a person. Kiln cracks can, in these, generally be detected before applying a test, but in the "boxed in" trap forms, while the closet has a better appearance, there are interior walls that cannot be examined, nor proved without a test. It is for this reason that many pedestal bowls have to come out when the final test is applied. The uncrazing vitreous ware (non-absorbtive all the way through) is best.

If a closet does not flush evenly from the rim, the holes can be "doctored" by jamming pieces of rubber in to reduce the flow at points. If a closet does not syphon when the jet hole and channel are clear, little or nothing can be done for it. Earthenware sometimes warps in the kiln so as to throw the jet toward one wall of the trap. This cannot be helped but they should not be shipped. There is usually a little swell in the surface adjacent to the jet hole, on the upper side,—this is to keep the bowl water from cutting across the jet with force enough to interfere with syphonage; the lack of proper form of surface at the jet hole may therefore thwart syphonage in earthewnare closets, but there is no excuse for failure in an iron closet.

The use of direct flushing valves for residence work has been greatly diminished because house service pipes are not large enough, and either water companies do not permit or the owners will not pay for large services. Fig. 213 illustrates a scheme allowing any size small service to be used where the pressure will answer at all. The volume of water ample for flushing accumulates below floor in the "air-tight" tank, to which leads a branch from the service and from which is a pipe to the flushing valve as large as the inlet of the valve. In the sketch, **SC** is a

cock on the service branch; **CK**, a check valve, and **D** a drain cock. The check prevents accumulated water from leaking back into the house service in case of the water being shut off, or heavy drawing taking place at fixtures. The missing after-fill of the tank, as supplied when the tank is above, is taken care of by the service water which has access to the flushing valve at all times,—the time to which the flush valve is set governs the flush and after-fill. The valve shown is one of the numerous market types. Muddy water affects some forms of direct flushing valves; others would operate with soft mud, were it supplied; most of such valves close against the pressure; all divert foreign matter from the controlling valve seat by means of strainers or otherwise; all have a means of timing the flush,—usually by a water pocket, spring or weight actuated. Seat action is provided for flushing valves, when desired.

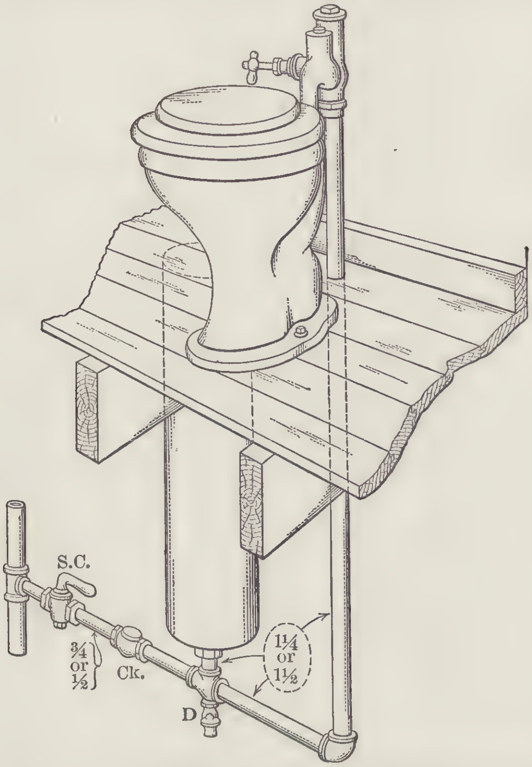


FIG. 213. DIRECT FLUSHING AS ACCOMPLISHED WHEN ONLY AN ORDINARY HOUSE SERVICE (TOO SMALL FOR DIRECT USE) IS AVAILABLE

For prison work, both valves and tanks are placed on the wall back of the closet compartment and operated by seat or pull action. Closets are also made for institution work in which the bowl bolts to the wall independent of the floor, the trap and valve or tank being on the opposite face of the wall, with seat or pull action, fitted through to the closet. When the seats are *fixed* to, or are integral with the bowl, as in many prison jobs, pull action must be depended upon. There is the same, even more, incentive for stripping all quarters of, loose weapons in asylum work, than in prison work, but insane persons are found to be indifferent to surroundings and are so careless that seat action closets are necessary. The seats are not left free to swing as usual but are pivoted back of the center in a way to give but limited movement, and are counter-weighted at the rear.

Both high and low closet tanks have the same features in the way of

flushing fittings, when the tanks are to be used with syphoning closets. There is no trouble experienced with swelling wood on high tanks because they are not deep, but the low tank being necessarily shallow from front to back is made high to give the required capacity. When the linings were fastened to the dry wood at the top and bottom, in the factory, as the shallow tank linings had always been, trouble with leaky linings ensued when they were put into use. This was partly due to light linings, to the narrowness of the tank, to light soldering, poor soldering, inside soldering, and to poor lock-seaming without soldering, but increasing height due to dampness did its share. This swelling was due partly to using lumber abnormally dry.

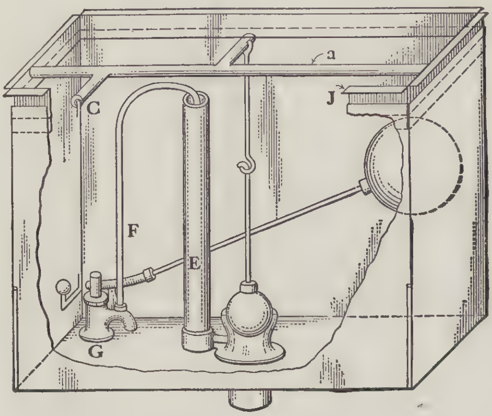


FIG. 214. LOW TANK LINING WITH HOOD AND TRIMMINGS

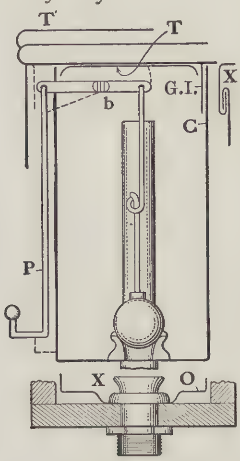


FIG. 215. END SECTION OF LOW TANK LINING SHOWING EFFECT OF SWELLED WOOD ON DIFFERENT STYLES OF LINING

The best results with low tanks come from giving the lining but little fastening other than so much as it is held down by the trimmings locked in place. A good way to do this is to stop the lining in the body near the top without a flange, and then, to prevent splash or condensation from running between the lining and the wood, place a flanged hood extending from the top edge of the tank to some distance below the top edge of the water-holding part of the lining, as seen at **J**, Fig. 214, in which the swellage travel is indicated by the distance between dotted lines, and from the dotted line to the bottom edge of hood, above **a**. The effect of swellage, at the bottom of a lining fastened at the top, is shown at **O**, Fig. 215, in which the increased height of tank is indicated at **T′** dotted line above the top. In the sketch above **O**, is shown the original form of the bottom, in which it should remain, so that the wood below it will sustain the weight of the water as intended. In Fig. 214 **a** is the tilting rod; **C**, a wire connection from tilting rod arm to push button, passing through a saw-cut in the wood back of the lining; **E**

overflow pipe leading to the flush valve; **F**, the after-fill pipe from ball cock nozzle to overflow pipe, and **G**, the ball cock. When the cock is placed at the bottom, no muffle pipe is necessary, but the after-fill must be extended up. The resistance of the water in the tank, the freedom of water entry to the nozzle, on account of differential area provided for the purpose and the friction of the nozzle, singly or combined, cause the water to rise freely in **F** for a sufficient time to raise the bowl water to the proper level. When the cock is at the top, a muffle pipe is extended down to reduce the noise of the entering water, and the after-fill pipe is short. In Fig. 215, **X** is the valve seat; above it, the hollow rubber ball valve usual for flush work is shown, seated. These balls, unless of very small size have a small hole in the bottom, supposed to reduce the pull of receding water below; **P**, is the push button rod; **b**, the tilting rod or shaft; **C**, is the tank lining,—it should be copper, at least 10 oz. to the square foot and would be better if 16 oz.; **GI** is the hood, before mentioned,—of galvanized iron; **T**, is a metal shield on the bottom of the tank cover, to keep it dry. The hood and lining are sometimes loosely interlocked as shown at **X** opposite **GI**.

Ball valves, like shown, float lazily for a time when pulled up, borne up by the water rushing to the outlet beneath, but settle down as the water level falls, and are finally jerked into place suddenly, by the suction, where they are held more and more firmly as the tank fills. There is a form of valve having a depressed bottom like formed by pressing in one side of a hollow ball; in these there is more or less void in the depression as it nears the seat.

For high tanks a goose-neck syphon which provides no after-fill is much used where the closet is non-syphoning. The goose-neck is offsetted so as to get the valve under its center of gravity, and is lifted by a loop cast in the top. With this form of valve a feather-edge washer seating in a flaring cup is used. The closet pull if lifted for an instant only starts enough water down the flush pipe to institute syphonage through the goose-neck. The syphonage continues until the water reaches the open end near the bottom.

The copper-lined wood-case closet tank has several competitors, the strongest probably being the cast iron tank enameled inside and outside. With these, contrary to what would be supposed, no perceptible sweating takes place under any ordinary conditions, though metals are used in the enamel. Solid porcelain tanks are freely used in some localities.

In Fig. 216, is shown an "air-tight" tank, about 8×24 in. used with many automatic seat action closets, and holding enough water under the average pressure to flush a jet syphon closet. The gauge pressures resulting from compressing the air contained from atmospheric pressure, are shown at the left of the tank, while at the right are the corresponding water depths, showing that 4.8 lb. pressure equal $\frac{1}{4}$th full,

and so on, to 44 lb. gauge or 58.8 lb. absolute pressure when the air is compressed to $\frac{1}{4}$th the original volume at atmospheric pressure. The sketch indicates the spud in the opening at the bottom, as extending above the bottom about 2 in. This is done to leave an after-fill depth, the after-fill running out slowly through the hole, **a** to the closet.

For jet syphons, the flush pipe hole is at **S**; for wash-down syphons it must be at **S′**, to allow the seat to be thrown back,—unless the valve used has a long stem, or the connection is offsetted. A tank can be turned to use the hole other than was intended by boring the bracket and removing the wall ear,—using a strap at the top instead. **P**, is a pipe plug.

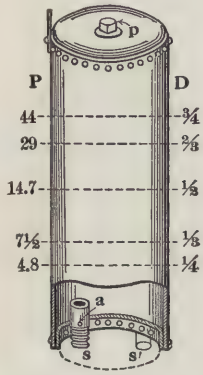


Fig. 216. Air-Tight Pressure Tank for Seat-Action Closet

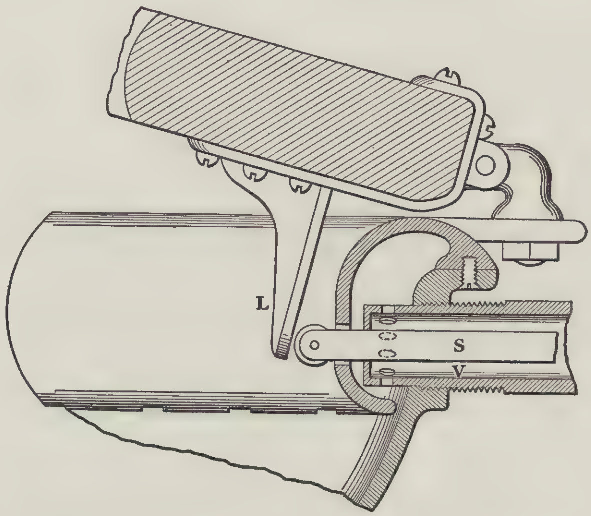


Fig. 217. Automatic Seat-Action Water Closet Valve

Fig. 217 shows the stem end of a valve like used with the "closed" tank illustrated in Fig. 216, screwed into a tapped boss on an iron closet. The boss is usually back from the wall of the closet a little, letting the water discharge into a cavity before reaching the flush rim. Earthenware closets are fitted in the same way, the stem end of the valve screwing into a spud set in as usual. **L**, is a seat-lug for operating the valve, **V**, by pushing in the stem **S** as the seat is pressed down. The end of the valve body is closed only by arms holding the eye for the stem to work through. When discharging, water pours through the end openings and those indicated in the wall near the end of the body.

In some forms of automatic closet valves the stem has had to thrust against the whole water pressure in order to keep the water out of the bowl while the tank filled. This requires the weight of an adult, and the strain on the seat is sufficient to soon rack it to pieces. Other forms of these valves have the plunger balanced so as to make the action of the

pressure on the stem almost neutral,—a rubber cushion or spring being used to return the pressure valve to its seat as the flushing valve opens when the seat is released.

No direct acting seat-action of this type is fit for the use of children as they invariably release the seat before an effective amount of pressure and flush water are stored. For child's use there are open tank closets with the seat held tilted by a counterweight. Depressing the seat lifts a rod, carrying the weight to above a trigger in the tank fittings; when the seat is released, the weight descends, carrying the trigger arm with it in a way to trip the flushing valve which then flushes the closet in the usual way.

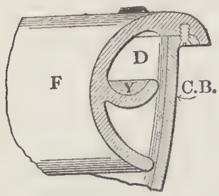


FIG. 218. SECTION SHOWING SHELF IN CLOSET FLUSH-RIM

There is one feature about iron closet flushing rims where the rim is cast separately, not found in rims cast on or made integral,—the separate rim leaves a way for some water to fall out at *all* points as well as at the ways purposely provided. Ordinarily the rim would for this reason be short of water at the front of the closet.

An adequate supply to the front is assured by casting a shelf in the rim as shown in Fig. 218, in which **CB** is the wall of bowl; **F**, the rim; **D**, the water-way above the shelf, and **Y**, the shelf, perforated as indicated.

The principles of a tank valve that may be regulated to close quick or slow, as desired, are illustrated in Fig. 219. It is shown to close with the pressure, aided by an outside spring **S**. The spring not only helps to pull the pressure valve to a seat but overcomes the resistance of the stem packing. While the valve is open, and as it travels in the direction pointed at **a**, flush water flows to the fixture through the side opening, and to the timing chamber in front of the cup-leather, as indicated at **a′**, **a′**, the cup-leather, **Y**, having moved to $\mathbf{Y}^1$ position. The stem may be instantly released, but the water continues to flow because the timing chamber has filled, and after the cup-leather reaches an unbroken wall as it is closing, pulled in **b** direction by the spring, the valve cannot close faster than the water in the timing chamber can flow back through the regulating channel in direction **b′**. The time of so closing may be prolonged or accelerated by reducing or increasing the area of the passage at the end of screw **A**. A washer, **A′**, with resilience enough to respond to ordinary regulation is used under the screw-head. By screwing in, the channel can be practically closed, prohibiting the valve closing at all except by leakage. All valves using the water to time the closing have this principle embodied in some form or other. A ditch scratched in the wall along where the cup-leather travels would permit the valve to close quick or slow according to the size of the ditch but regulating the time

of closing would with such be confined to a very small and unsatisfactory range.

A conventional ball-cock on the principle of the Jenning's diaphragm is shown in Fig. 220. Its action depends upon presenting the same water pressure per square inch to both sides of the disc used to close the pressure way, the side opposing the pressure having a greater area for the water to act on than that of the supply opening. It follows that with equal pressure, the larger area will hold the disc against the smaller one. Supposing the sketch to be a section of a ball cock in a tank, working conditions are seen to be brought about as follows: With the ball

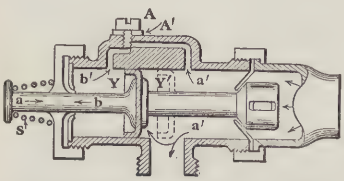


Fig. 219. Principle of "Time-Closing" Valve

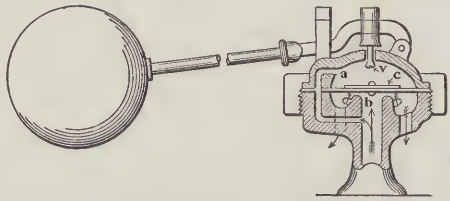


Fig. 220. Differential-Area Float Valve

down, the auxiliary valve, **V**, is open; water passes up the supply, lifts the disc **b** and pours down through the openings into the tank; at the same time, water passes through the side channel at **a** into the chamber above the disc, and after filling the chamber, overflows through the auxiliary valve, **V**, into the tank. When the water level reaches the ball, it is gradually brought up and finally carries the auxiliary valve to a seat with its lever, thus closing the outlet from the upper chamber. But little more water is then needed to take up the slack of the diaphragm, and it is supplied at **a** in a moment and the pressure above the disc is so raised to that in the supply pipe. When the pressure is equal above and below the disc (diaphragm), the disc is slapped down on the pressure seat with a surplus of force proportional to the pressure and difference of areas acted upon. For instance, if the supply has a 1-in. circular opening, and the opposing side of the disc is round and 2-in. diameter, and the pressure 30 lb. per square inch. Then, $1 \times 1 \times 0.7854 = .7854$, the area of the supply; $.7854 \times 30 = 23.56$, the pounds pressure acting on the supply side; $2 \times 2 \times 0.7854 = 3.1416$, the area of the opposing disc; $3.1416 \times 30 = 94.24$, the total opposing pressure in pounds; $94.24 - 23.56 = 70.68$, the uncounteracted pounds force with which the disc is held to the supply seat.

In practice the pressure seat would be a little lower than the surfaces clamping the disc, so the diaphragm would meet it only by cupping slightly; this provides slack so the pressure can lift it without undue strain. A metal clack, **C**, is fastened to the upper side of the disc to give it a solid bearing. This form of valve can be made to utilize a very small float in controlling large supplies under any pressure.

With simple leverage cocks for closet tank use the range of pressure that can be controlled is small, for room for the ball and length for the lever are both limited. The simple lever is made to answer for moderate pressure by reducing the area of the supply opening to a point where buoyancy of the ball used with the length of stem possible, will with a short fulcrum, exceed the force to be overcome. For high pressures, ordinary or simple leverage is compounded to increase the power as necessary.

Attaching closet bowls at the floor or wall is a feature of plumbing that has been given much attention; more perhaps than it deserves, considering the ease with which a good job is accomplished. The most

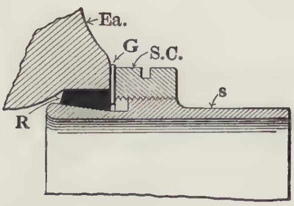


FIG. 221. EXPANDING GASKET CLOSET CONNECTION

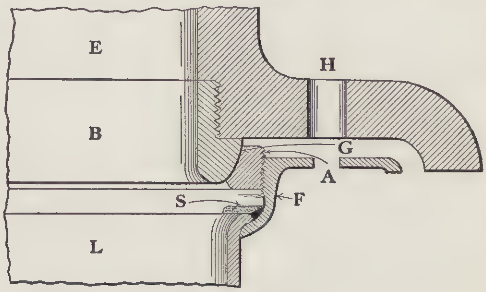


FIG. 222. GROUND-JOINT METAL-TO-METAL WATER CLOSET FLOOR CONNECTION

ordinary method, a poor one not likely to remain long efficient, is to flange the pipe over the wood, put common putty about wherever the base flange will bear and then clamp the bowl down with wood screws, screwing directly into the floor through the holes in closet flange. Another way amply safe and lasting for general use is to first solder to the pipe and then screw to the floor a brass floor-flange having "T" or beveled slots to receive the heads of closet bolts. The slots are enlarged at one end so the bolt heads can be inserted, after the flange is fastened down, and slipped along to the exact position required. The closet is set on the flange as usual and screwed down with blind head nuts run down on washers. Plaster or cement is sometimes used instead of putty, but these make it harder to remove a bowl, and the flange is hard to clean if resetting is necessary. Sometimes a thick soft rubber gasket is used over the nipple to make tight to the pipe, the pedestal being held as needed by narrow wood wedges. Plaster or quick-setting cement is then flowed under the balance of the base flange. When set sufficiently, the wedges can be withdrawn and their places filled.

The best possible floor connection is probably that shown in Fig. 222, it being a brass ground joint of the ball form, screwed to the closet, bolted to the floor and soldered to the pipe. This joint is not only permanent and firm but allows the bowl to meet the pipe at a slight

angle if necessary. In the sketch, **E** is the earthenware of the closet; **H**, bolt holes in the closet flange; **B**, brass spud with ground surface,—screwed up in cement in threads made in the earthenware; **G**, brass ring with ground surface to match grinding on **B**,—the height of the ring being adjustable by means of the threads **A**; **F**, the floor flange with bolt holes to match **H** and screw holes (not shown) to attach to floor,—having also threads for the adjustable ring **G**, and a lower end adapted to receiving the flange of the lead connection; **L**, the lead extension of the soil pipe, flanged into and soldered to **F**,—**S** representing the solder.

For closets that connect to a wall pipe instead of to the floor, the method shown Fig. 221, similar to an end opening porcelain bath tub connection, has been used. **S**, is the ferrule or spud; **SC** a collar with spanner holes to screw it up by; **G**, a metal washer to press the gasket in; **R**, a wedge ring of rubber stretched into place over the entering end of spud, and **Ea**, the earthenware. The spud is first attached to the pipe, so it projects out the proper distance; the collar is then run back flush with the recess wall; then the metal washer and next the gasket is placed over and back to the collar. The closet being placed and secured with the face of the earthenware about as shown in the sketch, the gasket is stretched up the incline all around until it tightens. The collar is then used against the washer to force in and expand the gasket to the degree of tightness thought necessary.

CHAPTER LVI

Range Closets and Urinals

Range closets consists of from two to 15 or 18 seats in length, and are installed single or double, with or without partitions and backs, as the style, conditions or location may require. Three lengths are allotted to seats,—24, 27 and 30-in., the narrow spaces being restricted to ranges for school children. One or more 30-in. seats with walls and door are frequently supplied, for teachers' use, with ranges otherwise fitted for shorter seats.

Ranges are invariably made of cast iron and are generally porcelain enameled on the interior. They are divided into two general classes,—the open troughs and those consisting of a manifold made up of seat sections bearing a seat opening or bowl, usually cast on the section. The manifold sections are in pipe form between bowls, and thus each seat is water-sealed from the other,—a construction that requires connecting the stack to each seat section when local ventilation is provided.

The ranges in which the bowls are thus sealed between are of the two general forms shown in Figs. 225 and 226. In Fig. 225 the bowl diverges from the top and floating soil thus, by gravity, falls away from instead of grinding against the surface as the level of the water in the section recedes. No flushing of the bowl surface is provided for Fig. 225, and the seat is bolted to the opening. In Fig. 226, the bowl surface converges as it does in an individual closet bowl. The bowl is provided with a flushing rim and seat lugs. The flush water is derived from a manifold flushing pipe supplied by a tank, and connected to each bowl. The spud areas where necessary are differentiated to compensate for the milder flow reaching the remote bowls, the smallest openings being placed at the bowls nearest the tank. The bowl shown is with integral flushing rim and the bowl itself is cast on the manifold section. They are also made with separate flush rims and with base flange to bolt to the manifold. All styles of sections belonging to classes Figs. 225 and 226, are supported by pedestals fitted to bosses cast on the bottom of the sections as shown. The small pipe, **a**, Fig. 225, is to relieve the air between the tank water and that in the manifold; without pipe **a**, there is considerable noise and a lack of free water flow in the inlet end when the tank discharges.

The emptying of ranges is now accomplished almost altogether by the pneumatic principle. This depends upon tank action and was adapted from Boyle's closet, as were most other pneumatic syphonage devices. The range type of outlet for pneumatic syphonage is shown

in Fig. 227. The tank which operates it is seen, at the right, in Fig. 230. The outlet is arranged to suit the fixture it is used with. In the section illustrated, the trap is for an open trough range. Its parts are bolted together. The level of the neck of the upper return controls the water-level in the range in all cases; its lower end is a spigot to enter a soil pipe hub and the lower trap, in the case shown, (usual for range closets), is a common vented (V) soil pipe P-trap. The air pipe, $\frac{3}{4}$ or $\frac{1}{2}$-in., has a union near the trap; it leads up and over to the tank at the opposite end

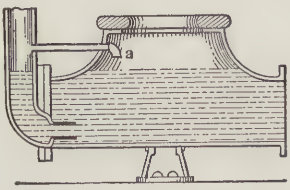


FIG. 225. RANGE SECTION WITH RECEDING SURFACE

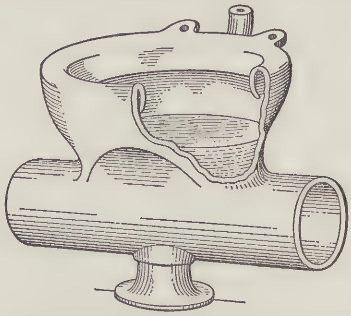


FIG. 226. RANGE SECTION WITH INTEGRAL FLUSHING RIM BOWL

of the range. When the tank discharges into the range the falling water sucks the air out of space **X**, through the pipe, and discharges it into the tank syphon. When the air is sufficiently rarified in space **X**, syphonage of water from the range occurs, but the action is broken in time to save a seal and a deal of water in the range body. The exciting action ceases when syphonage from the tank stops.

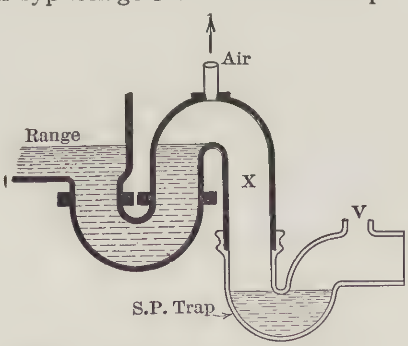


FIG. 227. RANGE OUTLET ARRANGED FOR PNEUMATIC SYPHONAGE

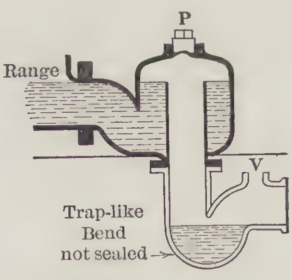


FIG. 228. CIRCULAR WEIR SYPHONAGE FOR RANGE OUTLET

An entirely different arrangement for syphon eduction is shown in Fig. 228. It consists of a circular pot, with an inlet neck for connecting to the range, in the center of which, projecting upward from the bottom to the desired range-water level, is a circular weir which serves for the outlet. Below the pot is a trap-like *bend* (not a trap),—the pot or

chamber above forms the trap. The weir retains the water in the range. When the tank discharges, water pours over the weir from all points, converging below the top of the weir in a way to form a water piston which sucks the air out of the dome. The water falls freely because the air below is not confined. As the dome becomes exhausted, water rises from the range and the fall through the weir becomes profuse, ending in true syphonage. When the water level reaches the neck of the pot, air enters from the range and stops the syphon. In some respects this action is superior to others as it depends upon the tank for water only.

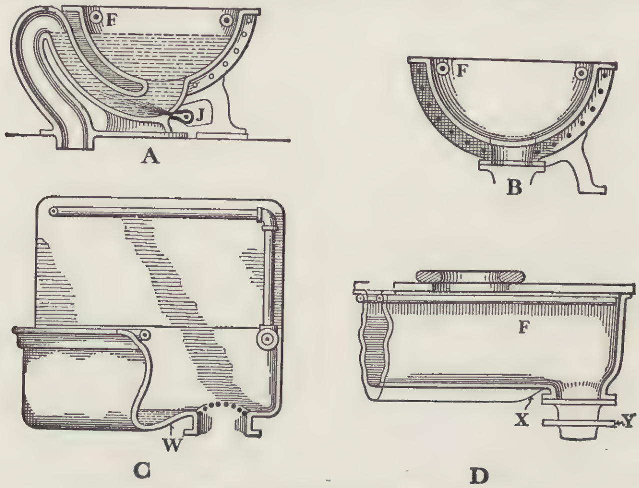


FIG. 229. RANGE AND URINAL TROUGH FLUSHING

The soil pipe is vented at **V** or some place near. Careful venting of soil pipe work on the same sewer with ranges is necessary on account of the large body of water discharged quickly at one action. Both the pot and the contorted bend are tapped and plugged so that drain pipes may be provided. The bend is not so likely to be damaged by frost, and can be "soaked" out through the plug **P**, but a drain pipe with cock should be fitted to the pot.

At **A** in Fig. 229, is shown a section through the trap of a jet syphon range closet. The jet enters at **J** and imparts its energy to the trap water in the same fashion as marks the action of the ordinary jet syphon closet. The trap is attached to a nipple on the center section of the range. Only trough ranges have been so fitted. The trap is usually supplied with a clean-out plate screwed to its crown. The flush pipes, **F**, traverse the length of the range at each side, but seldom cross the ends. They wash the surface above the water level. The wash-down pipes are generally $\frac{3}{4}$-in. perforated galvanized iron, with the line of holes turned enough toward the trough wall to cause the streams to strike it near the bottom of the pipe. Seamless brass pipe gives the best results. All

trough ranges, whether for soil or urinal service, are so washed above the water level. The troughs for soil ranges are supported by feet or frames under the trough, bolted to it at the flanges. The feet are indicated by dotted lines in sketches **A** and **B**, Fig. 229.

At **B**, dotted beneath, is a tapering outlet nipple flanged at the upper end. The taper is designed to make tight by sitting down in soft putty in a close fitting sheet lead shoe provided by the plumber,—the shoe being wiped on at the floor. Another form of nipple for lead pipe connections,—shown at **Y**, sketch **D**, has a double flange and a nipple projecting from one flange to enter the soil pipe at the floor level. The nipple is attached to the floor and soil pipe first, and the range bolted to the upper flange afterward. Such nipples are for what are called washout ranges. These have a sloping weir, as shown by the dotted line at **X**, sketch **D**, for the purpose of keeping a bed of water in the trough to prevent soil from sticking. When the tank discharges, a strong wash is thrown along the bottom from the inlet end; this floats the contents along the trough and over the weir, while the perforated pipes wash the sides. The seats of trough ranges are sometimes hinged to a frame attached to the trough flange as shown. A cheaper plan is the made-up cover of one thickness, with the seats sawed out in a way to leave strips between the seats,—the strips being framed to the part back of the seat line. The strip along the back and the strips between the seats are bolted to the range flange, front and back, and the seats hinged in their gaps.

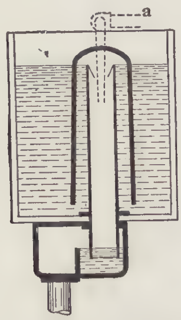
Syphon outlet ranges have no provision in the trough for retaining a water-bed,—the bottom is straight, as in solid line in sketch **D**.

A washout range urinal trough is shown at **C**, Fig. 229, the weir, the wash-down pipes, and the flush inlet is the same as just described for the washout closet range. Range urinals are fitted with a back, just as a sink, except they are washed down at every tank action by a perforated pipe leading along the top of the back, down the ends, across the trough ends and then along under a brass capping as indicated at **C**.

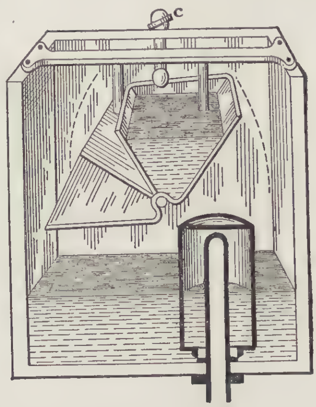
There is more reason to use brass wash-down pipes on urinals than on closet ranges,—that on the back is in full view, while the pipe in the trough is subject to more severe influences.

Urinal ranges with syphon outlet have a straight bottom to the outlet hole; are made in straight and lipped trough styles; are without the wash-down pipe along the front, and hang on brackets unless two ranges are placed back to back in the floor space, in which case they stand on supporting frames that bring the top of the trough 26 to 30 inches high. Range urinals are fitted with partitions and backs as required. The partitions are usually of cast iron, extending to the top of the trough only, but may be of marble or slate.

In Fig. 230, at the left, is shown a section of an automatic flush tank of the type used with range closets and urinals. Some of its virtue lies in the fact that there are no moving parts in the tank. When used with a syphon outlet like Fig. 227, the air pipe **a** is inserted in the top of the bell and acts as already described. For other types of ranges the bell of the syphon is closed at the top, as usual. The action is then about as follows: The weir pipe dips slightly into a shallow trap in the service box shown below the tank; as the tank fills, the air in the bell is slightly compressed; at about the level at which the water would overflow into the weir, the compression has acquired force enough to blow



Without moving parts



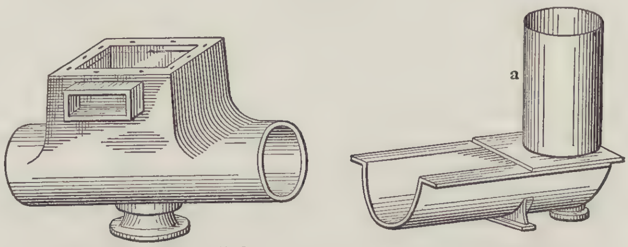
By tilting Bucket

FIG. 230. AUTOMATIC SYPHONING TANKS FOR URINALS AND WATER CLOSET RANGES

through the seal in the lower trap, and the vent thus given the air in the bell allows the water level in the bell to rise,—it having been previously kept below the tank water level by the air pressure; the impulse of water upward in the bell causes a liberal overflow into the weir pipe; this institutes syphonage in the usual way. Any interval of time desired between flushes can be obtained by regulating a cock or bibb on the incoming supply. These tanks are wood cases lined with sheet copper,—some have been lined with sheet lead, but in the larger sizes for long ranges they are heavy enough at best. The brackets supplied by the maker are frequently too light to trust. The flush pipe for ranges is 2-in. to 3-in. wrought pipe, screwed in at the tank bottom. At the range end the flush should be joined by a hub and spigot joint, as this is about the only way the plumber can be sure of having his flush pipe stand upright.

At the right in Fig. 230, is shown a time honored form of automatic tank operated by a tilting bucket and bell syphon. The same principle is carried out in various forms with cast or copper-lined body. The tank is mostly used on tank-flushed urinal batteries. In the sketch, **C**, is a regulating cock on the supply which enters at the top at the center of the end, high enough for the bucket to swing under it, and ends with

an ell where water will fall into either compartment of the bucket, one at a time, according to the position of the bucket. The dividing partition of the bucket vibrates between two pins that project downward from a bar crossing the top of the tank as shown. Under the partition is a saddle-bearing from end to end of the bucket, it rides over a rod shaft fixed in the tank body. The only positions in which the tilting bucket will voluntarily stand is with the partition leaning against one or the other of the two pins. Its center of gravity, when empty, is then so far from over the support, on the leaning side (left in the sketch) that the side in position to receive water requires to be nearly full before the weight on the filling side changes the position of the center of gravity to that side of the support far enough to tilt the bucket. When the



Individual Section Style　　Trough Range Style

FIG. 231. VENTILATING RANGE TROUGHS AND BOWLS

bucket tilts the water is emptied into the tank and the other side then fills until the weight of the filled side again tilts it, and so on. Repeated dumpings of the bucket contents fill the tank to a level where one more discharge will cause a good overflow down the stand pipe in the bell. The overflow is sudden and rapid enough to institute syphonage about as before described.

In Fig. 231, are shown two methods of venting range closets. At the right is seen the back of a seat section with a 2×5-in. rectangular nipple extension cast on, suitable for attaching an arm of a sheet iron local vent pipe. If vented at all, each seat of ranges water-sealed between seats must be connected up. The vent openings are sometimes plain bosses tapped for 2-in. wrought pipe, or circular nipples suitable for sheet pipe connection, according to style of range or piping.

There is but one way to vent a trough range. It is shown at the left in Fig. 231. A sheet iron pipe, **a**, usually 14-in. round,—about equal to the section of the trough, is fitted to a plate over the range at the outlet end. The seat work otherwise covers the trough. Covers for the seat holes must be used. One or two covers are kept up at the inlet end and the balance down. If the bumpers on the seats and covers permit much leakage, only one seat cover needs to be kept up. The vent may be carried out or entered into a flue.

CHAPTER LVII

Closet and Urinal Stalls

Fixture stalls are made of opaque honed glass, marble, soapstone and slate. Glass work is confined to the most expensive jobs. Marble in choice varieties also finds a place in high priced work, and of one variety or another is almost universal for stall work in the general run of jobs. Of plumbing marble in general, it may be said that Italian veined, Vermont and Georgia white, Tennessee, in gray, pink and mottled, Italian statuary, Spanish variegated and African are all used more or less, the quantities diminishing from the first named to almost none for the African, in about the order named, and the total for white varieties exceeding that for colors. Very little of the bright mottled (Hawkins Co., Tenn.) is used in plumbing for any purpose except lavatory slabs. The statuary marble (veinless) includes Parian and Carrara. Onyx is a banded Mexican Calcium Carbonate resembling the gem. The author has seen very little of the onyx and African marbles in plumbing except on lavatory work, but there are in the states many fine Spanish marble bath tubs cut from the solid block,—probably more in and around Philadelphia than in any other single district.

The average stall job is ordinary white or tint marble varying in cost from \$0.75 to \$1.00 per superficial foot of bare slab $\frac{7}{8}$-in. or 1-in. thick. The price varies some according to whether both sides and edges or one side and some of the edges are to be polished, and whether the slab is 1 in. or 2-in. thick. As a charge for polishing the edges of slabs, the thickness of each polished edge is added to the adjacent dimension of the slab before computing the surface.

Stalls vary in dimensions to suit specifications, but the following may be taken as standard. Height, for closets or urinals, (5-ft. 6-in. preferred for closets), 5-ft., or 5-ft. 6-in.; end slabs for urinal stalls, 24-in. deep and $\frac{7}{8}$-in. thick; urinal backs, 24-in. wide, center to center, and $\frac{7}{8}$-in. thick; urinal stall intermediate partitions, 20-in. deep and $\frac{7}{8}$-in. thick; closet compartment back and side slabs, $\frac{7}{8}$-in. thick; width of back slabs, 36-in. center to center; side slabs, 46-in. wide; jambs, $\frac{7}{8}$-in. thick,—width, 6 to 12-in., according to width of door and width of compartment; floor slabs, $1\frac{1}{2}$ to 2-in. thick, according to size of slab, countersink, etc.

Closet compartments ought to be as large as mentioned, but are frequently of less than 36-in. width and sometimes less than 4-ft. deep. The heights given take no notice of shorter lengths used with leg standards.

There are six general types of slab urinal stalls, all represented in Fig. 240; two plans for removing waste, and three service schemes.

For one or two stalls, the side slabs, and the partitions, if any, often reach from the floor up, like **A** and **A**[1] in Fig. 240. This makes a sound job and both the back and floor may be in two pieces, when there is a partition. But, unless the waste is gutter drainage, a full length partition makes two countersinks necessary, and also two floor drains, if such are placed at all. A plain general countersink will lead water to a gutter or strainer, but floor slabs in gutter drainage jobs are often channel sunk as at **H**

The usual type of partition for gutter drainage stalls is shown at **F**, the countersink leaving a band for partition footings but being otherwise general as at **G**, or channeled at **H**. For a single range of stalls the backs fit tight down on the back edge of the gutter. The joints in the back slabs are made to come behind the partition edges, and thus the necessary angles and bolts for holding the partition in place also serve to partly hold two other slabs. It is best to channel (shallow mortise) the floor slab bands about $\frac{3}{8}$-in. deep for the foot of the partitions to stand in. This makes a firm job and it is then unnecessary to use foot angles in the partitions. Double range partitions where gutters are used, are made like **F**, but the partition backs are generally cut short and held suspended between the partitions, as shown at the gutter of **A**[1]. In other forms a single gutter is used for each range and a double set of backs short, separated to give ventilating space are employed.

Some intermediate partitions are cut away at the bottom, in front, as shown at **B**, in order to permit the use of one general countersink for the range. This favors free circulation of air and makes mopping easy. These partitions and their backs must be well anchored to the wall if the range is single,—if it is double, there is an equal counter-pull of one partition upon another neutralizing the overhanging weight on each side.

Partition **C** is a modification of **B** using a leg standard, as at **d**[1], to take the overhanging weight. It serves the same purposes as **B**, and like **D**, which is a further modification of **B**, is mostly used on single ranges. Partition **D** is cut short straight across at the bottom and exposes a portion of the back joint as shown at **j**. Partition **E** is an abortive midget affair offering no privacy, being often not over 15-in. front to back. It is supported at the bottom, like **D**, at **e**[2], by a double-eared double-leafed stirrup in which the corner of the partition is bolted, —the ears being bolted to the backs. Common angles like shown at **e**[3] are generally used near the top of partitions in place of top fittings like shown at **e**. Top fittings are necessary at the front top corners of partitions over which a rail is placed. The object of a top rail is to stiffen partitions by means of standards leading down to them from it.

An example of straight top rail is shown in Fig. 240, at **o**-**o**^{3}, **o** being flanged to the side wall. This presumes the end slab of the range, **h**^{2}, to stand away from the wall. The rail is shown as though on the far side of a double range to avoid confusion in lines. Another example of top rail where there is no side wall within reach is shown at the right, **o**^{2} being the corner standard for **A**^{1} and **o**^{1} a wall flange at the end of a tie rail running to the back wall,—the range in this case being presumed to be single, with the backs standing away from the wall equal to the distance **a**,—some 10 or 12 in.

Saddle or stirrup fittings in straight and tee patterns, with and without ears, for every possible position in which marble may be used are kept in the regular stock of all jobbers, together with all the necessary angles, bolts, nuts and blind-tapped nuts. The best pattern of rail fittings are the plain ones. The most convenient type of stall leg and rail standard fittings for marble attachment are those with hub for the leg or standard to screw into, like shown in sketch 3^a, Fig. 241. All angles, floor flanges, bolts, standards, etc., used on closet and urinal stalls are made of brass, plain polished or nickel-plated.

Cement gutters and floors are provided for temporary stalls, such as for exposition work, race meets, etc., but for permanent jobs the gutter is cut in the floor slab, gradually deepening to the outlet end, or, cast galvanized or enameled gutters are provided and set as shown under **F** and **A**^{1} partitions at **K** and **L**. **K**^{1} is a single range gutter with level flanges at both edges, the rear flange having a vertical lip turning up behind the back slab, which keeps the back aligned from the rear while the partitions hold it straight and in place at the front. **K**^{2} is the back slab, sitting on the rabbet formed by the lip on the rear flange, and **K**^{3} the floor slab lying on and projecting over the front flange into the gutter space. Both of the flanges are bedded with cement or plaster before the marble is set in place.

A double range gutter is shown, set, at **L**, **L**^{1} being the gutter; **L**^{2} and **L**^{3} the floor slabs, set as before mentioned; **L**^{4}, partition back slab held suspended over the center of the gutter, between the partitions, by means of the angles attaching the range partitions,—**L**^{5} being a partition of the rear range, and **L**^{6}, one of the front range, as, say, **F** or **A**^{1}. At the discharge end of the gutter is fitted an outlet piece changing from open gutter form to that of a soil pipe spigot-end for the waste pipe to attach to. At the gutter end of the mouth-piece is fitted a vertical grating. The lengths of gutter are flanged and are bolted together. The edge of the grating projects between the flanges of the end and mouth-piece like a gasket, and is bolted up between two gaskets, or with cement or putty between.

With gutter drainage, some form of spray cleansing is necessary.

The most usual form of flushing is to wash the surface of the back slabs by means of a perforated brass pipe, as shown at **W**, Fig. 240, attached to the slab about $3\frac{1}{2}$ ft. above the floor. Range backs thus water-washed are not always fitted with dividing partitions, as such provide a deal of side fouling surface not ordinarily fitted with flushing pipes. If fitted with partitions, the spray pipe is held in place by the notches necessary for it in the back edge of the partitions. The end of the supply is carried through the end slab and capped; if the fitting at the opposite end of the range is not close, the finishing end can be lock-nutted, or a ferrule of larger supply pipe can be slipped over the supply line between the

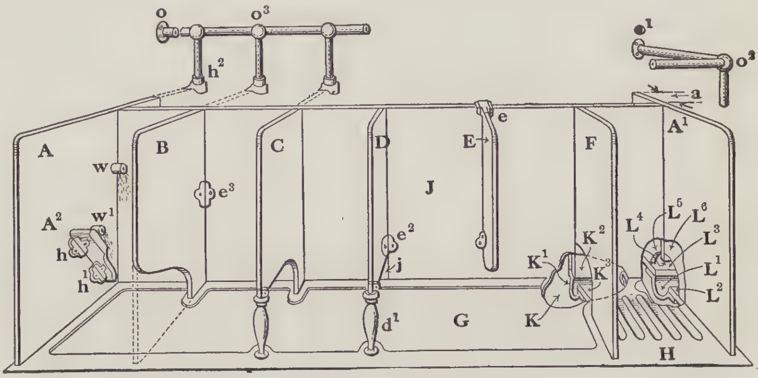


Fig. 240. Seven Styles of Urinal Stall Partitions Assembled on One Back for Comparison

fitting and the end slab, at the supply end, to hold the pipe steady.

If an iron pipe is used and the work is temporary, the spray holes can be quickly punched accurately enough, with a common center punch sharpened at an angle of about 45 deg. The surface around the holes will swell upward in punching. This can be peined down if necessary to reduce some of the holes. It is a good idea to couple hose to the pipe after perforating and try the holes under pressure,—some may thus be found too small or too large or at an angle, while it is easy to punch and pein them into shape to give a uniform sheet spray. For permanent work the supply should be striped and the holes carefully drilled. Holes drilled in brass neither wear nor corrode enough to seriously affect the alignment of the spray.

For continuous or periodic spraying, a loose key stop-cock is fitted in the supply. This can be set, and turned on and off only by the use of the key. If a range is long, it is best to enter the supply at the center of the spray line. For intermittent flushing, automatic tanks are used,—of the same kind as are employed for range closets and urinals.

Occasionally, a range is fitted with a deflecting slab, like shown at **A²**, to catch drippings and thereby keep the floor dryer and cleaner.

These slabs are set inclining from the back at an angle of about 30 deg., the top edge being about 2-ft. from the floor slab and the bottom edge hanging over the gutter space, but not touching the floor slab by an inch or more. Two angles are used at each end of the deflector, as shown at **h** and **h**^{1}. When the space is too wide for the deflector to stand without intermediate support, marble feet, cut to the proper slant at the top, are set under from floor to deflector and secured to it by angles. The upper side of the deflector is provided with a spray wash by a pipe run along near the top edge as shown at **W**^{1}, the supply being a separate line from the outside or a branch inside from the main line at **W**.

The most general use of stalls is that of housing individual flushing rim urinals, flushed by direct connected self-closing cocks or by intermittent tilting bucket or syphoning tanks,—the only floor drainage being that from the countersink through a floor trap, with grating at the surface.

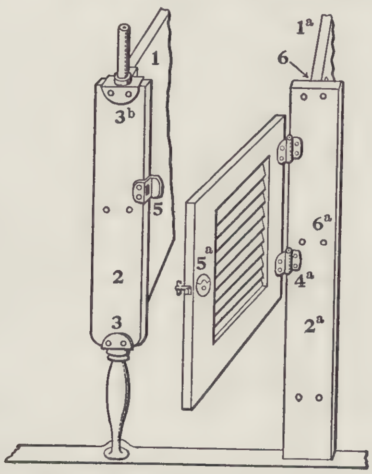


FIG. 241. CLOSET STALLS PARTITIONS WITH JAMS FOR DOOR TRIMMINGS

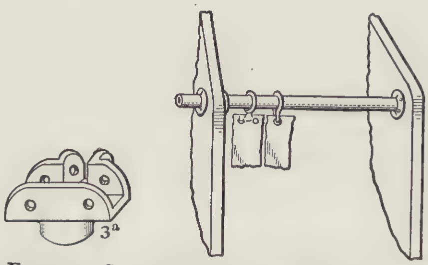


FIG. 242. SHOWER STALL PARTITIONS WITH CURTAIN ROD ANSWERING IN LIEU OF TOP RAIL

Two styles of closet door jambs are shown in Fig. 241. One is the compartment side slab or partition and 2, a jamb; the front edge of the side, and the jamb, are supported by a leg standard, 3, the top of which is a tee-channel like shown in sketch 3^a. The top fitting, 3^b, is the same as 3^a, inverted. With it is shown a portion of the rail standard. Stalls are not high enough to bind the jambs with a marble head or rail, direct, so, as a binder of some type is necessary to help resist the shock of opening and closing doors, a pipe rail is connected to the jambs by means of standards long enough to hold the rail $6\frac{1}{2}$-ft. or more above the floor. This adds to each jamb the combined resistance of all and incidentally gives corresponding rigidity to the side pieces.

Besides being bound to the side slab at the top and bottom, there are two angles at the center of jamb 2, the bolt heads of which are seen near 5. A brass saddle with a projecting lip in line with one leaf, and provided with a lock-bolt mortise, is bolted to the left jamb, as shown,

by means of two small bolts,—this piece, marked 5 in the sketch, is called a door "Strike."

The style of jamb shown at the right, 2^a, in Fig. 241, is more stable than the shorter leg-supported kind. All intermediate compartment sides stand at the height of a leg standard above the floor, regardless of whether the jambs extend to the floor or not. A side slab, though it be the first of a series (open to view from the toilet room space) may have a projecting jamb like 2^a, if thought necessary to stiffen the structure through giving it the wider footing. Though not shown at the right, a rail standard fitting belongs at 6. Other reference markings on jamb 2^a are: 1^a, side slab; 6^a, jamb angle bolts; 4^a, spring door hinges, and 5^a door indicating spring latch. Turning the latch handle on the inside, to lock the bolt, brings the word "occupied" into view on the dial outside. Compartment doors are made any length to suit the persons concerned, and of widths to suit jambs and compartment widths,—usually about 24-in. The door panels may be solid or louvered. There is no advantage in the slats except, perhaps, that they are unsuitable for poetry,—ventilation being otherwise accomplished, and doors of equally as light weight easily made in the solid.

With high partitions like often used for shower baths, curtain poles like shown in Fig. 242 can be made to steady the marble in lieu of a top rail, while at the same time serving as a bar from which to suspend the curtain necessary to the entrance.

CHAPTER LVIII

Toilet Room Safes

In cases where toilet rooms are placed above apartments of a character making it essential or advisable to leave no chance of damage below from leaks or overflows above it is usual to not only protect the supplies by casing them, but also to make a safe pan as large as the entire room. The safe is preferably of sheet lead and is often placed upon a floor at the general floor level or some two or three inches below and the toilet apartment floor raised some 5 or 6 in. or more by setting within the safe pan, a set of 2×3 or 2×4-in. sleepers upon which the second floor rests. The safe pan is made to extend as high or higher than the toilet room floor, and thus the lower ends of the wainscoting, being wood or marble, come safely below the top edge of the walls of the pan. If the supply comes from below, it is brought up into the safe in a casing of wrought or cast pipe, solder connected to the safe at the upper end. Above this there can be no leakage but that will find its way to the waste pipe of the safe pan. If the toilet room floor and wall, say to wainscot height, is tile or marble it is a safe in itself, for leakage or chance water that may find its way to the floor, can be piped out or dropped through a trap into the pipe of the safe pan below. If there is marble under the fixtures only and tile between, the slabs should be countersunk. At least one floor drain, a trapped affair with a 2 or 3-in. grating or strainer, (**D**, in Fig. 250) should be put in to transfer any chance overflow out or to the safe below instead of allowing it the opportunity to flow over the threshold.

The author has fitted rooms as large as 13×5 ft. with 2-in. countersunk marble floor in one piece, about as indicated in Fig. 250,—in which **S** is a lead safe pan reaching up the walls on all sides to about the height of **P**; **S. W.** is a safe waste pipe from the pan to the open, and **O**, a gravity flap like placed on the end of the safe pipe to prevent air from circulating through the pipe,—the clack is propped open during the summer months. **Z** indicates a series of blocks placed on the safe under each sleeper,—these are to hold the sleepers up so possible leakage can pass freely to the safe pipe from any quarter; they also afford a means of making up any unevenness that may exist in the lower floor or in the sleepers. When the sides of a lead pan turn up high, as shown, the corners may be cut out and the seams wiped or soldered up, or the corners can be folded, as preferred by the workman or dictated by the shape of the stock which the pan is to be formed of. The cost is about the same either way.

The walls of the lead pan are sometimes made shallow as shown in sketch **J**, Fig. 250,—**J** being the bottom and **L. S.** the sides. Higher side walls are then provided to any height desired by galvanized sheet iron represented in the sketch by **G. I.** Iron is stiff and when lapped in the pan as shown needs only to be nailed to the wall at the top edge and tacked to the lead with solder at intervals, while lead is more costly needs sound support along the top edge when the pan is very deep and

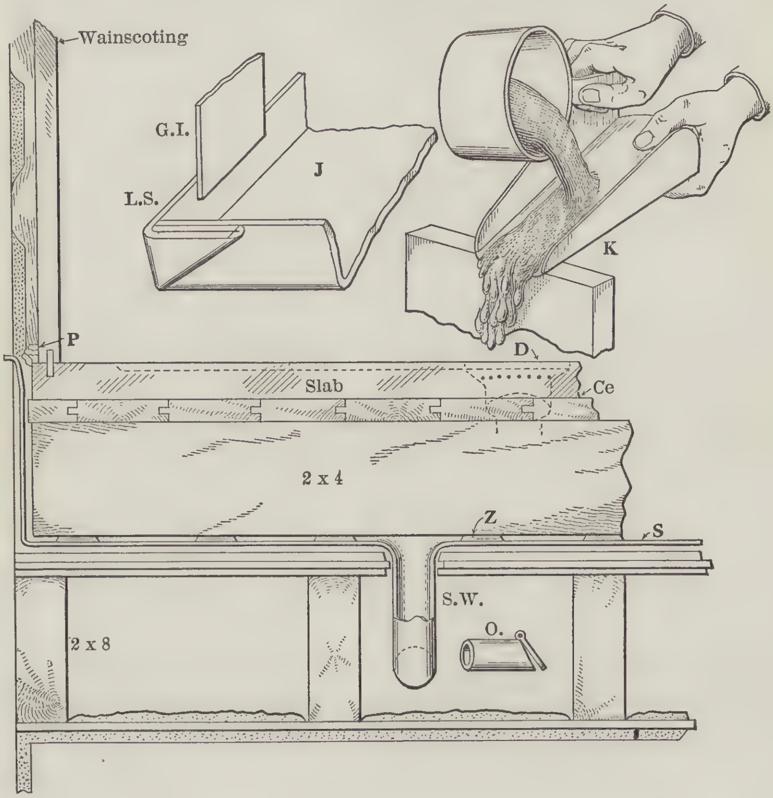


FIG. 250. TOILET ROOM SAFE PANS AND WORK PLACED WITHIN THEM

may also need fastenings along the sides between the bottom and top edge, which would have to be soldered or spot wiped over the same as would be required for a tank lining. If such work is done in an old house, the plastering is cut away along the top edge of the pan and the lead pinched into a joint and pointed over with cement. If a tile floor is to be laid, the sleepers must be shallow enough to give the proper bedding of cement without making the step-up too high. If the floor is to be a marble slab it should be bedded in portland cement (**Ce**) thick enough so the slab can be jostled down level by jarring it when in place;

bits of wood should be bradded to the floor here and there before the bedding is spread, placing their tops on a level. This insures that the slab once in place will not settle out of level before the cement sets. The bedding should lack some of reaching the edge of the slab.

The wall slabs may be doweled in line as indicated near **P.** There should be some space left all around between the back of the wall slabs and the wall,—this is shown at **P**, choked loosely with paper so plaster can neither quite reach the floor slab nor run down so as to choke the water shed when filling behind the wall slabs. The house plastering is knocked off in spots to give the plaster of Paris a bagging hold on the wall,—this is not necessary where the slabs sit on a firm marble floor as in Fig. 250. When a plastered wall is covered with marble, care must be taken to see that there are no holes through to the studding space, otherwise, plaster may waste into the studding space,—crumpled paper will answer for stopping key cracks, but plaster is best.

Presuming a slab anchored and ready to fill behind, the plaster should be mixed quite thin like milk so it will not choke the space high up, and in small lots at first so the weight of the stack will not force the bottom through, before it sets. Pour in a half gallon at a time, here and there, in some order easily remembered, and then repeat the operation in the same order as soon as it is thought the first pouring has had time to set. After the bottom has been made safe, presuming there was a drip space to be preserved as before mentioned, the plaster may be mixed in larger batches and dipped up and poured, or poured from the larger vessel direct as fast as possible, in one place until it is filled. Then move to another place and fill it. One need not fill the entire space,—filled to the top, as mentioned, at intervals of two feet or more will, with the anchors, be ample, for the mass spreads at the bottom. If a continuous back support is wanted for a cap, rolls of crumpled paper may be tamped down 3 or 4-in. in the gaps and the filling then completed from the paper to the top. The object of pouring very thin stuff at first is to keep from choking the space all the way up by unavoidable clinging layers along the slab and wall which also set while the bottom mass is setting. The reason for rapid continuous after pouring is to keep driving the previous pouring down to the mass before it gets a chance to set. Otherwise one pouring would have a skin of more or less thickness on both wall and slab that would stiffen in the interval; the next pouring would deposit another layer of a thickness according with the consistency of the stuff poured and some of *it* would stiffen or set. Thus, successive coats setting one on the other would reduce the space at the top so the bottom could not be filled. If scant filling is desired, mix the plaster to the consistency of thick syrup, pour it in slowly and wait for the clinging layer to set before pouring more,—this is sometimes a good plan for partially filling big spaces merely to

bind a slab more firmly than the anchors alone hold it. Loose fitting anchor holes sometimes allow a slab to chatter, though it is otherwise safely enough anchored to depend upon without filling.

The plaster cannot easily be poured directly into a wall space, so for conveniently directing it, a piece of sheet iron or tin can be bent up on two edges and down some at one end so as to form a shoot about 3 or 4-in. wide at the discharging end and 6-in. at the holding end, the lip being bent down or in opposite direction to the sides, at the narrow end. This makes a handy trough to pour in,—used as seen in sketch **K**, Fig. 250. The lip is a feeler-guide by which to keep the shoot in position.

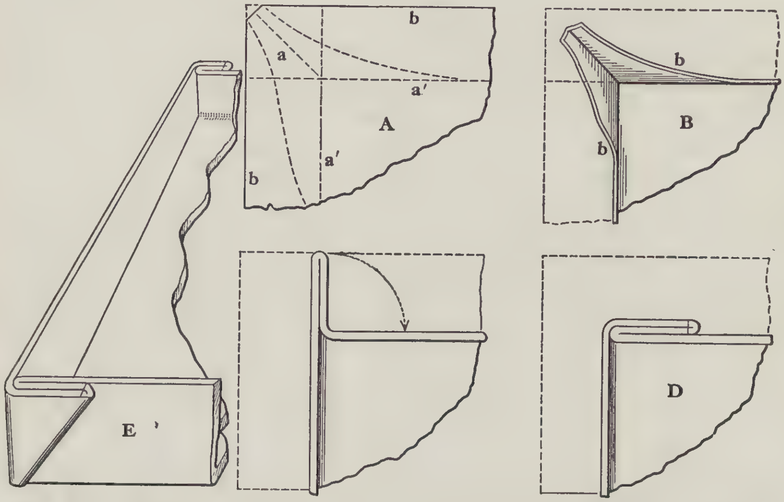


Fig. 251. Method of Folding Lead Safe-Pan Corners without Soldering

In Fig. 251 is shown the progressive stages of folding the corners of a safe pan as shown finished at **J**, Fig. 250, and at **E**, Fig. 251. The sides are first marked off as per **a′** dotted lines, and the corners clipped, as in sketch **A**. The edges, **b**, are then bent upright along the sides, except near the corners, where they are left standing about as shown by the curved dotted lines, the double along the miter line, **a**, being partly made, and all looking about as the edges **bb** do in sketch **B**. The corners are then dressed up to the angle desired, using a block on the inside,—the double being closed and dressed to alignment with one side as shown in sketch **C**. Next, the corners are dressed around in the direction of the arrow in sketch **C** until moderately tight against the side or end as shown in sketch **D**. The corners then appear as seen in the perspective sketch **E**, are absolutely tight without solder and do not need solder tacking at the corners when the sides are of ordinary depth.

CHAPTER LIX

Setting Marble

Regardless of location there is no plumber but that is sooner or later called upon to "set" some marble work other than that of merely bracketing up his lavatories and bolting together, on the job, stalls that have been fitted and verified at the works before shipment. In some sections a deal of this work is done by the plumber. The ability to handle marble reasonably well increases a journeyman's value to his employer. Because, to say the least, the "setter" is then, on ordinary work, always on the job just when needed, and the plumber and helper do not need to sit around on the job nor be provided with work elsewhere at the loss of time consumed going back and forth while the boss pays someone else to do some odd portion of the marble setting needed during the process of pipe work. The plumber is not regularly provided with every facility afforded the marble cutter and is generally not as fast, but on the whole, when the plumber does the setting, time and money are invariably saved, unless the job is a large one, and in a location where competent setters can be landed on the ground on short notice.

If the plumber has kept his eyes open and wits about him, both as a helper and as a journeyman he has learned some good points about this work, though he may not know that he can saw gaps for pipes and cut odd pieces with speed and safety with a common hack-saw; that he can bore any ordinary size hole, by hand, with flat or twist drills; that for large holes, it is better to take the center out by boring the hole with a small drill first; that the bite of the drill and pressure brought to bear should be such as will keep the drill cutting continuously, insuring rapid work without soon dulling the drill; that where the hole is large and the pressure, necessary to make the drill cut, hard to apply or likely to cause "breaking out" too much on the opposite side, two drills sharpened at different angles can be used alternately,—one with an acute point deepening around the center, and the other lowering the border, left mostly at the wall of the hold; that very large holes can be border marked or scored on the scribing on both sides of the piece with a small narrow keen chisel, pitching inward, or, with a worn out brace washer-cutter sharpened to cut a channel as a rotating chisel, using a small center-hole for a center,—the body of the hole being afterward pitched out with a chisel, working from both sides, and finally rasped into finish at the edges; and, that medium holes can be first scored, then drilled $\frac{3}{8}$ or $\frac{1}{2}$ in., and finally flaked or pitched out,—working from one side by pitching outward from the surface, on the same side, or outward

from the hole,—working from the opposite side. None of this work requires anything that a plumber has not at hand, and it covers the usual range of job-setting with the exception of actually finishing an edge, a job rarely done and not coveted by marble men out of the shop. The plumber has means at hand for leading screw-holes. If he feels justified in preparing further, he can buy facing chisels and can saw-tooth the edge of a thin, short cold chisel so it will square down an edge with less danger of flaking out too deep in the side surfaces.

Any mechanic who willingly undertakes to do something not strictly in his line of work usually takes pride in doing it well. It would be hard to find a piece of marble so set, that was put up out of alignment or that became loose or crooked afterward, though of course, the methods of plumbers differ more or less from those of professional marble men,—the real cause of the permanency, for the plumber has not learned just how far he can take risk and come out whole, and generally would not care to court the risk on such occasions if he did know. Everyone can call to memory loose or leaning caps, bases, panels, wainscot slabs, etc., seen here and there, even in public buildings, that were set—in the usual way—by expert workmen under strict supervision; *but*, when a conscientious plumber gets through with fastening up a piece of marble it is there to stay as placed.

Fig. 261 illustrates the preparation for and the placing of a screw-hook top anchor for wainscot slabs, lavatory backs, with shelf over, mirror frame pieces, etc. Three holes are first bored large enough for the hook, the center one being made the deepest, as indicated, all at about the center of the edge of the slab and separated equal to twice the radius of the hook-head, about as shown in sketch **A**. The marble stock between the holes is then dug out with a narrow chisel and the pocket trimmed out to the diameter of the holes and rounding in the bottom to a depth of the radius of the hook end plus the diameter of the hook, and then some; then, in the back edge of the slab and even with the center of the pocket, drill a hole to the pocket and square up the upper half so as to make a round bottom channel that will allow the hook body laying in it to be below the top of the slab. The idea for thus cutting the pocket and channel being that the hook should rotate in the pocket when the body is bedded in the slot. This work is shown and indicated in sketch B. The location for the anchor being found on the wall so the slab will stand as desired when the anchor is in place, the anchor is screwed in until the hook-head is directly over where the pocket will come, and the hook left turned up, as shown in sketch **C**. When the slab is in place the anchor is twisted over and bumped around so that the hook sticks down as dotted at **C**.

Whether a wall slab is altogether held at the top by anchors of this kind depends upon the character of the wall; if it is such as can be

plaster filled behind the slab, merely so anchoring the work so it will stand as wanted until the plaster is run and set will insure permanence of alignment. Hook anchors, or horizontal dowels wired back are often placed in the joining edges of wainscot slabs near the top edge; the anchors thus require but one hole and the bedding channel. The hooks are screwed in obliquely in the bedding channel and then bumped into place,—this requires bending the hook to just the right angle with the body, and the body must also be bent some (to counteract the obliqueness at which the body screws into the wall) in forcing the anchor back in the bed beyond the joining edge line. No such methods should ever be employed on plumbing marble.

Three types of foot anchors are shown in Figs. 262 to 264. When wall slabs, partitions or backs are to be anchored in position at the floor over floor slabs, it is only necessary to bore corresponding holes in the floor and upright pieces and set in brass rod dowels as illustrated in Fig. 262,—$\frac{3}{16}$-in. is amply large for a brass dowel for any purpose; iron is not recommended for foot dowels but may be of the same size if used, and should be varnished. If a slab is to be anchored to a side wall simply to keep it aligned, the bottom edge line can be found and the anchors set for single holes in the bottom edge.

It will be necessary to bed the anchors as shown in Fig. 263 only where the slab touches the support,—at other points they can be screwed in below the bottom line. There is no need for pockets for bottom anchors because the slab is free to be moved and the anchor does not have to be turned while the slab is in place.

When screw anchor dowels like shown in Fig. 264 are the best means of aligning a slab, single holes bored straight into the bottom edge are all that is necessary. The slab should not be left to stand solely upon such anchors. Sufficient wedges or blocking of some material that will not let down should be placed under the edges at intervals to make sure the slab remains as set, otherwise it may in time lean edgewise or bear heavily against the adjoining piece.

Fig. 265 is a section showing a wall slab and cap on a lathed and plastered wall; **a** represents the house plastering and **PP** the plaster of Paris filling between the slab and plastered wall. The slab is held in at the top by an anchor like shown in **C**, Fig. 261. The house plastering is indicated as cut away at **P** so the wainscot cap could be bedded in the wall back to the lathe line. Bedding the cap, as shown in the sketch generally brings its center of gravity to a point over the wall slab and thus it would not tilt by its own weight if not secured in any manner other than by laying it in place. This is not always the case, however, and besides, fastening is necessary to take care of chance weight, strain and jarring. Usually, nails or screws are run in over the cap at convenient points, as shown at **N**, to hold the cap down and keep it

steady before pointing up the wall. The cap itself should be set in a cream of plaster of Paris previously laid on the top of slab and filling. In some cases instead of using the brads, **N**, small slanting holes are drilled in the top of the cap just back of the plaster line, and small bodied wire nails driven through them into the wall. The plaster space **P** is finally filled and pointed out flush with the wall plaster line. **S**, in Fig. 265 is a wall studding.

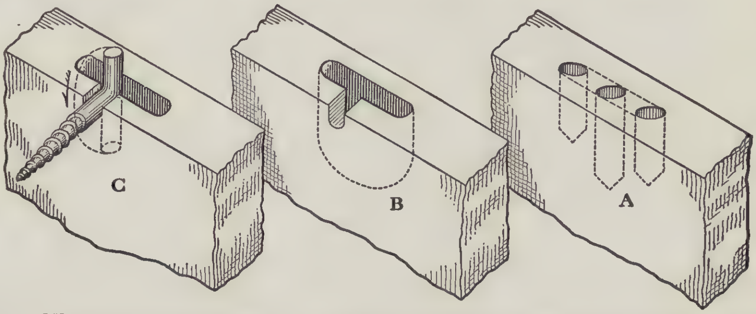


FIG. 261. WAINSCOT, WALL SLAB AND MIRROR FRAME TOP ANCHORS—PROCESS OF FITTING

It is sometimes necessary, or at least more convenient, to remove a marble lavatory slab for the purpose of setting a new bowl. Unless provision for doing so is made in the original setting, this cannot be done without also removing the lavatory back. If the back is a simple slab

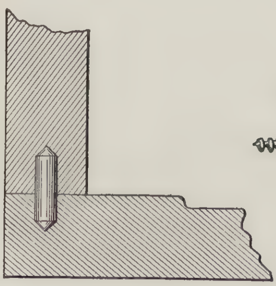


FIG. 262. WALL SLAB DOWELS

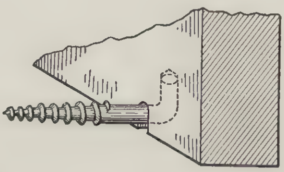


FIG. 263. WALL ANCHORS FOR BOTTOM OF WALL SLABS

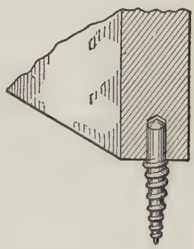


FIG. 264. SCREW DOWELS FOR BOTTOM OF WALL SLABS

and properly put up this is a small matter, but if there is a shelf or shelf and mirror frame over it and all is built up continuous, the removal of the work above the slab may alone be a serious matter. The object of Fig. 266 is to illustrate a very simple plan for obviating any necessity for disturbing the work over the slab. It shows a portion of a bracket, the back of a lavatory slab and a portion of the back above it, together with their fastenings. **Bk** is the back and **B** the slab bracket. Instead of doweling into the slab to hold the back in line and to prevent the slab from slipping away from the wall, the back is held at the bottom by an anchor as shown and like the one in Fig. 263. The slab is kept in place

by screw **a** passing through the shelf-face of the bracket. The slab may be leveled either at **a** or at the point of the bracket, as may be necessary for the particular job. The bracket will perhaps be found square and the wall not plumb. If the wall line cannot be altered, the bracket may be filed or ground, if not too much out, but ordinarily a leveling screw at the point or heel is best, for it provides also for future adjustment should such become necessary.

There are two ways of leveling a slab; one way is to wedge or block the slab up level with sheet lead or other material and run a common wood screw through the bracket and the wedging into a leaded hole in the slab; this method answers both for leveling and keeping the slab in position. Another way is to tap a hole in the bracket to receive a $\frac{1}{4}$-in. set screw, which, screwed up or down, raises the slab from or lowers it to the bracket face. Some brackets are too light to stand threading or have little strength when they are threaded. With such, the first method is imperative. The principal use for leveling screws is to discount obtuseness or acuteness of the angle of bracket faces,—cast brackets are seldom square and it is generally expensive, if indeed advisable at all, to square them. One is fortunate if a slab needs raising at the back instead of at the front,—the end of the bracket then touches the slab and looks better than when there is a gap,—supposing there to be no apron. When the back edge is to be raised, the slab is easily pushed back into place, some cream plaster can be strung along under the edge of the back without difficulty, and the slab screwed up level, against the back as previously designed. In addition to two anchors like the one shown in Fig. 266, there are usually two secret anchors in the back of a lavatory slab, about one-third of the way from the top and from the ends. The position of these anchors may be elected so as to utilize the best wall fastenings available. In preparing for the slab screws, **a**, or any other, a $\frac{1}{4}$-in. drill is first run into the full depth that will possibly be needed to seat the screw-head; a $\frac{3}{8}$-in. or larger drill is next run in about $\frac{1}{2}$ in. or so; then anchor holes are drilled obliquely or the big hole is dug out larger below that it is at the surface; next the screw is set vertically in the hole (a small nail flattened at the end and wedged in the slot will aid in so holding it) and hot lead poured in around it. The lead should be calked lightly while warm, before removing the screw.

If a bracket is acute and the wall plumb, the leveling has to be done at the point as shown in Fig. 267, in which **L** is a set screw and **B**, the bracket. If there is not room for the set screw hole beside the center web, put the screw at the point, filing away some of the web, if necessary. The slab can be kept from slipping away from the wall by letting the set screw project a little into the hole, but the point of a bracket is not a good place to anchor a slab to, because the bracket is too fragile, the fastening too far from the wall and the bracket flange at the wall too

narrow to resist side strain applied at the point. An apron slab like indicated in Fig. 267, though aprons are not the rule for bracket supported slabs, looks much the best. The apron is an especially helpful feature where the slab has to be leveled at the front edge.

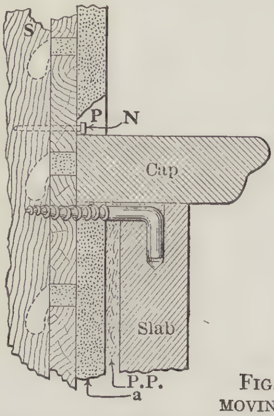


FIG. 265. SETTING WAINSCOT CAPS

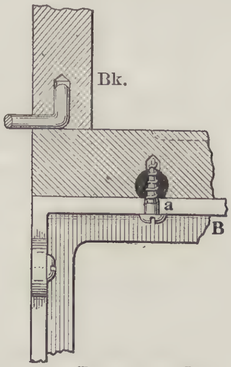


FIG. 266. PLAN FOR REMOVING LAVATORY SLAB WITHOUT DISTURBING BACK OR OTHER WORK ABOVE

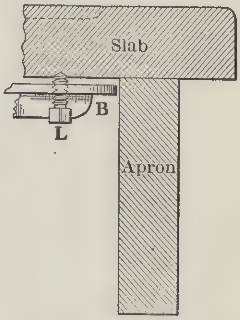


FIG. 267. SLAB LEVELING SCREWS

In Fig. 268 sketches **D** to **H** illustrate various steps in cutting the hold for a secret anchor for a lavatory back or mirror frame. One $\frac{1}{4}$-in. hole is drilled in the back of the piece at the proper point, say $\frac{5}{8}$ in. deep; a second hole, the same size further down and somewhat further away than the distance from the end of the hook end of the anchor to the

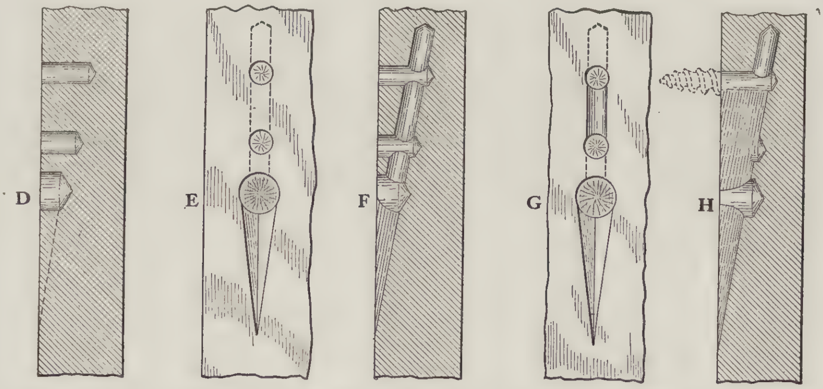


FIG. 268. LAVATORY BACK ANCHORS FOR SECRET FASTENING—PROCESS OF CUTTING AND DRILLING

back of its shank is then drilled about $\frac{1}{2}$ in. deep; a third hole, larger, $\frac{3}{8}$ in. or more in diameter, and about $\frac{3}{8}$ in. deep is then placed nearby, all about as shown in sketch **D**, and all in a line as shown by plan view **E**. A channel or ditch is then begun some distance back from the big hole

and gradually deepened to it, as shown in **E** and by dotted line in **D**. With a breast drill a slanting hole is next drilled through from one hole to the other and to fully the length of the hook-end of the anchor screw-hook beyond the first hole named, all as shown in sketch **F** and indicated in plan **G**. The stock between the two $\frac{1}{4}$-in. holes is then dug out as shown in **G**. If this is easier to do by also knocking out the wall between the middle and big hole, the whole stock from the channel shown in **E** to the anchor hole may be cut out as shown in **H**. The hole for the anchor head being slanted away from the wall, the end of the anchor enters before the slab touches the wall and drawn the back to the wall surface tightly as the marble is pushed down into place on the slab. The places at which the anchors will find a good hold in the wall must be first sought and the position of the screw hooks in the wall thus accurately established with reference to the slab, before marking off the anchor holes on the back.

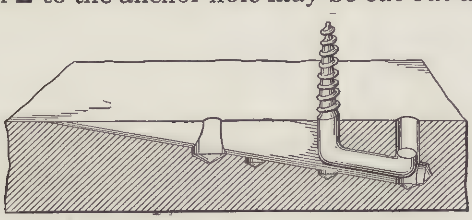


Fig. 269 Showing the Anchor in "Ceiling" Position

The author has found rare occasions for supporting one end of a piece of marble overhead without showing visible fastenings.

This can sometimes be done with an anchor like shown in Fig. 269 it being the same as shown in Fig. 268, except a hole is drilled down to the slant-hole for the nib on the end of the hook, and also the holes are placed further apart and deeper so as to give as much strength to the supporting bridge between the holes as possible. This anchor, like the one shown in Fig. 268, requires sliding of the slab to lock it, and the slant hole must be as large in diameter as the nib and hook together, measured from end to back.

CHAPTER LX

Weights of Plumbing Fixtures

The following will aid in approximating the weight of some fixtures in allowing freight for estimating costs.

One soon becomes familiar with the weights of fixtures most often used in a particular locality but for the run of goods occasionally used, the probable cost of which may be called for any day, some sort of guide for freight allowance is valuable and the weights here given will often be found a material aid, especially for preliminary estimates.

Syphon Range Closets:—For 2-seat 30-in. seat range complete, bare 750 lb.; for each iron partition, 130 lb.; for each 30-in. back, 180 lb., and deduct 6 lb. for each inch narrower than 30 in. on backs less than 30 in. wide; for each seat or section more than two, add 150 lb. to the weight of bare 2-seat range complete without partitions.

Open Trough Range Closets in general:—For bare 2-seat range, complete, (5-ft. trough) 700 lb.; for each iron partition, 130 lb.; for each back, 150 lb.; for each seat more than two, add 190 lb. to the weight of bare 5-ft. trough range.

Syphon Range Urinals:—For 4-ft. trough, complete, 500 lb.; for each partition, 60 lb.; for each additional foot of trough, complete without partitions, add 50 lb. to the weight of 4-ft. trough fixtures.

Washout and other Types of Trough Urinals:—For 4-ft. trough, complete, 375 lb.; for each partition, 60 lb.; for each additional foot of trough, complete, without partitions, add 40 lb. to the weight of 4-ft. trough fixture.

The above range fixture weights allow for trough, inlet, outlet, trap, flush pipe, tank, brackets, legs or feet, and seats, as required by the styles mentioned, but no allowance is made in the bare fixture weights, for backs, partitions or their braces, nor for full length partitions, jambs and doors for private compartments, such as are often provided on one or more seats of school ranges where special provision is thus made for the teachers.

General Marble Goods

There being such a variety of sizes and thicknesses of marble slabs in common use, it is best to figure the weight of lavatories, stalls, wainscoting, floor slabs, etc. The average weight of marble per cubic foot is 170 lb. The length by the breadth in feet, by the thicknes of a slab in inches will give the thickness of the contents considered as a chunk 1-ft. square; this divided by 12 will give the cube feet, thus: A slab

4 ft. by 7 ft., $\frac{7}{8}$ in. thick weighs how much? $4\times7=28$; $28\times0.875=24.5$; $24.5\div12=2.0416$, the cube feet in the piece; $2.0416\times170=347$, the pounds weight of the piece, taking the average weight of marble. Actually instead of figuring as above, for a small lot, one would say, mentally, $4\times7=28$; $28=2.3$ ft. and 2.3 times $170=391$,—say with $\frac{1}{8}$th off to equal $\frac{7}{8}$ in. thick in place of the 1 in. thick, 350 lb. for the piece. To this must be added the weight of crating lumber which weighs about 3 lb. per board foot.

Table XXIV. Bath Tub and Receptor Weights

Enameled Tubs crated nominal size of tub	4 ft.	4½ ft.	5 ft.	5½ ft.	6 ft.
Modified French shape, 2¼ in. rim, lbs. each	295	310	345	375	420
Modified French shape, 3 in. rim, lbs. each	315	345	375	405	450
Modified French shape, wide rim, lbs. each	—	—	450	500	575
Roman shape, 3-in. rim, lbs. each	375	410	450	510	580
Roman shape, wide rim, lbs. each	—	—	465	515	595
Add for boxing any kind (boxing exceeds crate weight) lbs	75	80	90	100	115
Add for tub with base (exceeds weight on legs) lbs	—	60	80	105	—
Add for wall tub with one side and one end exposed (exceeds weight of tub on legs) lbs		Lbs.	on any	size,	275

Roll rim receptors, crated, 3 ft. sq., 250 lbs.; 3½ ft. sq., 350 lbs.
Sitz baths, enameled iron, crated, large size, 200 lb., small size, 160 lb.
Foot baths, enameled iron, crated, large size, 175 lb., small size, 150 lb.
Porcelain tubs; weight, 800 to 1200 lbs., according to length, style and crating.

Iron and Porcelain Lavatories

The sizes and shapes are too numerous to detail or to hazard even a condensed list of approximate weights based on averages of market stock. A 20×24-in. iron lavatory with apron, and back 10 in. high, boxed with an off grade of poplar weighing about 30 lb. per cubic foot might be taken, as it does in some cases, to weigh 135 lb.; if without apron, 115 lb. But, different lavatories of the same make and size, as well as of different makes of the same size, vary in weight because of varying thickness; crating and boxing methods vary in different factories and boxes for the same lavatory made of $\frac{1}{2}$-in. $\frac{3}{4}$-in. and $\frac{7}{8}$-in. lumber vary in weight as the thickness, so there is no certainty. If the weight of a porcelain lavatory the same size as given above be taken to be 200 lb. when boxed, the actual weight will be found to vary from it for the reasons given. Lavatories are small fixtures, however, and there being a greater number of them used than of any other fixture, the average weights of so many are soon known that one can usually approximate other weights from the weights of the make he uses with greater accuracy than could be done from a rough average of the whole market.

Regular jet syphon earthenware water-closet bowls, lightly crated as shipped from the potteries, weigh 60 to 65 lbs. If recrated in straw in barrels or boxes by jobbers, the shipping weight is then about 100 lbs.

Government weight (80 lbs.) bare jet syphon bowls may be taken at 100 lb. crated and 150 lb. boxed.

Wood water closet tanks, copper-lined, crated for shipment, may be taken to weigh 45 to 50 lbs.

Enameled iron jet syphon tanks with cover, double enameled to prevent sweating, can be counted at 100 lb. shipping weight.

Water closet seats with covers, crated for shipment, may be allowed at 10 to 15 lb. according to kind and thickness.

An 18×30-in. kitchen sink, enameled, crated for shipment. weighs 40 to 50 lb.

All of these weights vary more or less because of variation in the thickness of wood and metal, character of wood, crating or boxing, etc. but all the weights given are close approximates for estimating purposes, and many other weights may be safely inferred from them.

CHAPTER LXI

Yard Fountains

Fountain jobs are not so numerous as to keep every mechanic familiar with the work. One way of piping the waste to a yard fountain is shown in Fig. 275, from which the principles to be carried out in the drainage of any fountain may be observed. Whether the premises be public or private, the same work is to be done, though the basin and pipes of municipal work are usually larger than those of private jobs.

It rarely falls to the lot of the plumber to design the basin or attend to building the retaining walls. Basins are almost invariably circular. A conical bench is usually left in the center of the basin which, with its sloping sides, gives a section through the center something like that shown in the sketch. The size of the bench or mound, through which the supply rises, is made to suit the fountain fixture. All sediment collects on the ring of low surface surrounding the bench and the waste pipe is brought through the bottom at the lowest point. The overflow is shown entering at the bottom, but it may be entered higher up and on the waste pipe side if desired. As shown is a better place than near the drain pipe, as the current to the overflow causes more sediment to collect on the overflow side and there is thus less chance of the drain being banked over when needed. The overflow should be protected with a netting to keep leaves and other trash out of the waste pipe. The drain should extend a couple of inches above the bottom so that a reasonable deposit of sediment will not interfere with it acting promptly. A bee-hive strainer or netting should cover the outlet.

Three or four inches of 1:2:4 stone concrete lightly tamped makes good basin walls. About 5 per cent. of slacked lime mixed with the concrete makes it more waterproof. To the rough wall is commonly added an interior surfacing coat of rich mortar plastered on from ½ in. to 1½ in. thick, the original surface being well wetted before covering. If thick, the surface can be troweled to a close finish before it hardens, sprinkling the surface with pure cement and finishing it in with the other. Sometimes, if the surfacing is hardly more than enough to even up the roughness of the stone mixture, two or three thick coats of cement mixed to a cream are painted on with a brush, allowing a day's interval between coats. The vertical walls should be heavy below ground to withstand the thrust of freezing and should extend below frost and have some batter so the earth will tend to lift away from the wall as it rises by frost. Above the ground the walls may be given any form desired.

The pipes are best laid before the basin excavation is shaped. The earth should be rammed back on the pipes as solidly as it was before digging out. The drain is usually wrought pipe, 2 in. or less, while the overflow line is more often 3 or 4-in. vitrified clay, with a piece of wrought or cast pipe set in for the upright. A better job is made by using cast soil pipe for the overflow line, as far as it is covered by the basin. All of the pipes may be laid in one trench unless the overflow line is necessarily too shallow for the supply,—then, the supply should be run out in a different direction. The drain pipe need not be at a higher level than the overflow. If it is higher, as shown, and in the same trench, it should

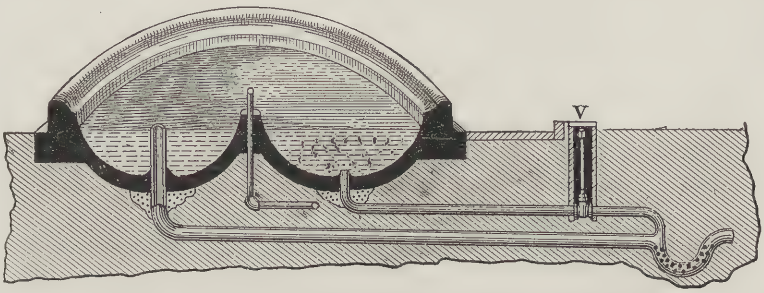


Fig. 275. Yard Fountain Supply, Waste and Overflow

be carried upon a bench of undisturbed earth. It should be made up complete and set in as one section, from the fountain end to beyond the gate valve or cock in the box. It is a good idea to place a union near the cock between the cock and the connection to the overflow or trap, and to place the trap near the cock,—not over 3 ft. away.

When the pipes are set, a bed of good concrete enveloping the bend and reaching up to the bottom wall should be rammed in around the pipe. This concrete should be made of quick setting cement so its setting will not delay the other work. The purpose of thus bedding the pipes is to hold the overflow upright and firm, and to help resist strain should it afterward be necessary to disturb the cock or drain pipe. To be rid of the projecting overflow while the wall work is in progress, it can be extended from near the bottom to the proper level after the basin is finished.

The cock box can be a regular road box, or a home-made tile, cement or wood box with iron cover. The key rod can have either a socket or forked end wired to the cock and may be furnished with either a wheel or a key-end near the top of the box, as at **V**, Fig. 275, all according to the form of box. If a valve is used, the rod may have prongs to hook into the valve handle, and at the top, a wheel or key-end. Also a long service key can be used on a cock fitted with the regular corporation box. The best form of cock for such use is one with a threaded flange cast on so the box bottom can be screwed to it, over the head,—there is

then no chance of the cock or box shifting, and no foreign substance can find a way in. The supply can be fitted with the usual stop and waste cock, or with a combination stop and waste valve,—situated somewhere near the drain box.

The question of fountain fixtures is one to be studied in connection with the catalogues of such goods. Such fixtures are numberless and range from simple sprays to the most elaborate massive bronze pieces, alone worth a modest fortune.

PART IV

CHAPTER LXII

Waste Pipe Nomenclature

The following relative to the significance of various trade terms used in connection with soil, waste and vent pipe work is here given to aid the reader in understanding more clearly what is meant when reference to pipes is made by name without descriptive details.

"Drainage," "sewerage" and "waste" are terms of a generic nature frequently used indiscriminately in naming pipe systems. When naming a complex system, the term that will indicate its functions or predominating service most clearly should be used. "Sewer," derived from the Latin, exaquatorium, a channel for water to flow in, is the parent of all collective names for outfall pipe systems.

"Drainage" is perhaps best understood to mean roof and surface water carriage and is a good descriptive name for the pipes conveying such. The pipe carrying soil from water closets is distinguished from others through the term "soil pipe." "Waste" when used by plumbers as a qualifying term, instead of as a collective name for all the outfall carrying pipes of a job, is understood to be the waste from sinks, baths, lavatories, etc.,—soil and storm water not included,—hence the term, "waste pipe."

Efforts to define the service by the name has brought into general use many phrase names that are more or less indicative, such as "*drainage*," "*storm drainage*" and "*storm sewerage*,"—for rain water; "*sanitary drainage*" and "*sanitary sewerage*," for systems carrying soil and the accompanying fixture water alone, or in common with other house outfall; "soil pipe *system*," "*stack*" or "*vent*"; "waste pipe *system*," "*stack*" or "*vent*"; "sink waste," (signalized because it carries grease), and so on, to more minute subdivision of each system, prefixing "*branch*," "*lateral*," "*stack*," "*main*," "*local*," etc., according to position, function, relative size or importance.

Drain Cesspools

A numberless variety of small cast sinks known as cesspools are made for taking care of surface inflow from areas, cellars, yards, and hydrants. The average conditions prevailing for service in different locations have resulted in cesspools being made in shapes more or less suitable to the different uses they are employed for. While there are many designs in each class, the cesspool used is still often poorly adapted to

the service required because a favorable shape is not in the market or none of the right form could be had in the locality of the job.

A fault with the ordinary hydrant cesspool is the lack of a flat grating or perforated plate to rest on lugs near the top of the basin, on which a water bucket could sit while being filled. Hydrant cesspools are made without traps and have an integral strainer over the outlet nipple. If a trap is used with them it is usually of clay and placed near or under the cesspool. The idea of the open body or basin is to prevent splashing as water falls in from the hydrant. Both the slop-sink and trapped stable types of cesspool, are too deep and usually too costly for common hydrant work. But few forms of the slop type are suited to setting a bucket in the basin.

The bell-trap cellar cesspool, in order to maintain an unbroken floor line, has the grating flush with the top, and, for hydrant use would so cause splashing; the nipple in many makes is too small; it is not trapped and is without a strainer when the perforated plate carrying the bell is removed, and so, in ordinary forms is suited only to cellar or area use, when the depth of the sewer makes a shallow fixture necessary. The side outlet cellar trap with cesspool body will not do for outside use because the waste would be broken by freezing ground. Where an outside cesspool discharges into a simple line ending in a street gutter or elsewhere on the surface, it is wise to use a trap in the line in cold climate work to prevent a current of cold air from freezing up the interior, layer by layer, in cold weather.

All regular bell-trap cesspools have a bottom outlet. The regular form has a square tapering body varying from 9-in. to 12-in. deep and 12-in. to 16-in. square for common use, to 16-in. deep and 24-in. square for stable purposes. The grating is at the top in all common forms. For stable and dairy use the body and grating must be strong enough to sustain the tread of stock, and the fixture must therefore also be substantially installed. The waste pipe hub and the surrounding earth alone should not be trusted to for support. A ring or so of brick laid in cement mortar on solid earth in a way to support the bottom of the basin is easily provided and assures permanence.

Out-door slop-hoppers or cesspools are like the deep cesspools so far as the body goes, but the grating rests on brackets cast on the walls some distance from the top, giving a basin above the grating large enough to hold a bucket of slop. Peelings and other waste that should go into the garbage can is strained out and retained by the grating. A trap bell is usually rivited to the bottom of the grating, but the bell may, either in hoppers or regular cesspools, stand loose, inverted, on feet, over the upward projecting outlet nipple. The depression around the outlet nipple serves to hold water for the bell to seal in, and to catch

dirt and hold it where it can be removed by hand, instead of allowing it to drift into the pipe, as it otherwise would. In some forms of slop-hoppers or cesspools, the grating is a deep removable basket form serrated on sides and bottom. With this form a trap must be used in the drain line.

In Fig. 300, is shown a form of yard cesspool, partly home-made which the author has found very serviceable for shallow drain lines where trouble from frost would be encountered with either a line trap or trapped cesspool. It gives the utmost depth of seal level possible for a shallow drain; any depth of seal desired may be provided, through the dip of the outlet bend; any depth may be left below the bottom of the bend for sediment to collect in, and any size sediment cavity thought necessary to stagnate the velocity of flow through the body so it will readily drop its sediment, can be easily provided. As dust and litter from pavements, paved areas, and sometimes earth surfaces, are swept into such sinks by the water during showers it is essential to provide a good size sediment cavity (more than is found in market fixtures), especially when the cesspool is situated where roof leaders do not flush its portion of the drain, or the fall available is small.

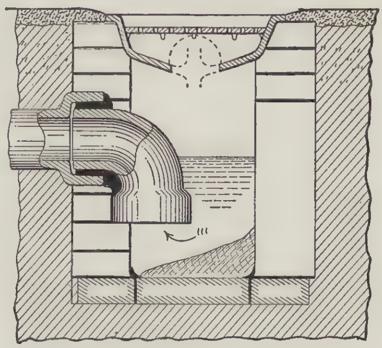


Fig. 300. A Shallow Cess-pool Adapted to Yard Use

So far as the brick work of the fixture shown is concerned, the illustration tells most of the story. The outlet bend and the brick about it should be laid in quick setting cement so it will soon be firmly held in place, but Portland cement is best for the balance of the well work and is essential for the top and facing as it does not weather like other kinds. The cesspool used was an area bell-trap sink, of the shallow type, 12-in. square over the flange. The bell was removed from the grating and the bottom of the sink broken out with a hammer, because the outlet was too small for yard use. The portions removed are indicated in the sketch by dotted lines. When the lugs to hold up the grating are mere tits, the top of the sink must be placed below the surface if any basis depth is desired; if the lugs are bracket-like, extending down the sides of the body until they die into the taper of the sides, the top of the lugs can be broken away to let the grating set down below the top flange, as shown.

The sink snown in Fig. 300 is in some respects like an outside grease trap, the principles of which, for the flotation type, would be complied with by giving the well a solid cover; providing an inlet similar to the

outlet shown, at about tne same level, and bringing a partition wall from the bottom between the inlet and outlet to a little above the level of their bottoms. The body of a grease trap should be 18 to 24 in. diameter, according to the size of the waste. It may be of round tile; of cement, with square or round form, or of brick. Flotation of the grease would take place if the inlet should discharge above the outlet level, but not so readily nor effectually as when the waste first submerges the grease in the cool water in the well and then floats it up to the surface. If the partition of a grease trap be omitted it is best to enter the waste above the level of the water, else part of the grease will drift over and rise to the surface inside of the outlet bend and thus find its way into the waste line. The very purpose of a grease trap suggests that it should be placed as near the sink it serves as is consistent with local conditions.

CHAPTER LXIII

Proportioning Local Vent Pipes

In laying out local vent stacks and laterals it is not only more economical in material, but also sometimes essential to the saving of room to keep the sectional area of the main closely proportional to the volume to be carried at the various points. To have the area of a lateral somewhat larger than the aggregate of its intakes is far better than to have it at all too small at any point. Where the draft is induced, greater care must be taken with relative proportions than when the draft is forced.

For round air pipes for local vent work, or for general room ventilation, a table of relative carrying capacities enables one to quickly decide many points affecting the proportions of runs without making lengthy calculations. The ratios in Table XXV were calculated from the usual formula, the number of small pipes being represented by the square root of the fifth power of the quotient derived by dividing the diameter of the larger size by that of the smaller.

To use the table, on 2-in. to 26-in. sizes, trace down from the main, and to the right from the branch size, in left column,—at the intersection in the line of ratios will be found the number of smaller pipes for main sizes 28-in. to 60-in., trace up from the main size and to the right from the branch size in left column,—at the intersection will be found the number of small pipes. This, for the larger sizes, applies only to the triangular patch of figures in the lower left hand corner of the table. For example, how many 18-in. branches will one 48-in. air main supply? Answer: 12.

A feature of Table XXV is the velocity per second, under $\frac{1}{2}$-in. water pressure (.288 oz.), through 100 ft. of pipe 1-ft. in diameter, and the discharge in cubic feet per minute through same. Up to 26-in. these are found at the intersections of equal sizes in the main portion of the table, while from 28-in. to 60-in. they are placed in the first couplet of lines above the main sizes,—"**V**" standing opposite the line of velocities and "**C**" opposite the line of cubic feet per minute, in every case.

Velocities per second for pressures not given may be roughly inferred from the fact that it takes four times the power to double the velocity. Thus, on the 12-in. size for instance, 15.5 ft. velocity per second may be presumed for .125 water pressure; 61 ft. for 2-in., and 122 ft. for 8-in. pressure; likewise, the delivery may be approximated for other pressures from the deliveries given. Thus for a given distance, pressure and delivery:—

Distance divided by 4 equals delivery multiplied by 2; distance

multiplied by 4 equals delivery divided by 2; pressure multiplied by 4 equals delivery multiplied by 2; pressure divided by 4 equals delivery divided by 2.

With any given pressure and delivery, find the delivery at any other pressure by multiplying the given delivery by the square root of the selected pressure and dividing the product by the square root of the given pressure.

With any given delivery, and specific gravity,—to find the delivery under like conditions for a fluid of a different specific gravity:—multiply given delivery of known specific gravity by the square root of the specific gravity of the different fluid and divide the product by the square root of the given specific gravity,—Quotient will be the required delivery. Thus, the deliveries at 0.35 and at 0.70 specific gravity would be about 400 and 285 cu. ft. respectively as against 240 cu. ft. delivered at specific gravity of 1.0,—all other conditions being equal.

If the diameter of pipe, and cubic feet per hour required are known and it is wanted to know what pressure in inches water gauge will deliver that certain amount, multiply the square of the required delivery by the specific gravity of the fluid, and then multiply again by the length of delivery pipe in yards,—term this product **A**. Then multiply 1822500 (constant) by the diameter of the pipe raised to the fifth power,—call this product **B**. Then the quotient derived by dividing product **A** by product **B** will be the required pressure in inches of water.

If the diameter of a pipe is required that will deliver a given quantity through a given length under given pressure, multiply the quantity in cubic feet by the specific gravity and then by the length in yards. Divide this product by constant 1822500 multiplied by the pressure in inches of water. The fifth root of the quotient so derived will be the diameter of circular pipe needed.

A difficulty to many in figuring sheet iron stacks and laterals for local vent and other work is due to the fact that much of the work is fitted with rectangular pipes. A square pipe does not deliver, area for area to equal a round pipe. Rectangular shapes other than square also vary from the square pipe and from each other somewhat according as the ratio of perimeter to sectional area varies.

The carrying capacity of pipes of the same area but of different shape is proportional to the quotient of the square root of the perimeter, or circumference, divided by the perimeter or circumference, as the case may be. Also the relative delivery of round and rectangular pipes can be readily and closely approximated by a chart based on the flow of liquids through pipes, deduced and diagrammed from Weisbach's formula by Mr. James A. Donnelly. The chart, Fig. 305 stands, in its entirety, it may be said, for the capacity of round pipe without dimensions,—the curved line measuring, by the divisions, the comparative capacity of

Table XXV. Equalizing the Capacity of Air Pipes. Number of Smaller Vent Pipes One Main or Larger Branch Will Supply. Velocity per Second and Discharge per Minute in Cubic Feet at ½-in. Water Pressure. "V" in Table Equal Velocity per Second, Found in Feet at Intersection of Corresponding Sizes on Sizes 2-in. to 26-in., and Over Sizes at Bottom on 28-in. to 60-in. "C" in Table Equals Cubic Feet per Minute, Found the Same as Directed for "V"

Diameter of Mains / Branches		2-in.	3-in.	4-in.	6-in.	8-in.	10-in.	12-in.	14-in.	16-in.	18-in.	20-in.	22-in.	24-in.	26-in.
2-in.	V. C.	**1** 12.4 16.0	**2.7**	**5.7**	**16**	**32**	**56**	**88**	**129**	**180**	**239**	**313**	**398**	**493**	**605**
3-in.	V. C.		**1** 15.0 45.0	**2**	**5.7**	**12**	**20**	**32**	**47**	**65**	**88**	**114**	**145**	**180**	**219**
4-in.	V. C.			**1** 17.3 90.0	**2.8**	**5.7**	**9.9**	**16**	**23**	**32**	**43**	**56**	**71**	**88**	**108**
6-in.	V. C.				**1** 21.3 252	**2.1**	**3.6**	**5.7**	**8.3**	**11**	**16**	**20**	**26**	**32**	**39**
8-in.	V. C.					**1** 24.5 515	**1.7**	**2.8**	**4.1**	**5.7**	**7.7**	**9.9**	**13**	**16**	**19**
10-in.	V. C.						**1** 27.4 900	**1.6**	**2.3**	**3.2**	**4.3**	**5.7**	**7.2**	**8.9**	**11**
12-in.	V. C.							**1** 30.5 1440	**1.5**	**2.1**	**2.8**	**3.6**	**4.5**	**5.7**	**6.9**
14-in.	V. C.	**38**							**1** 32.4 2160	**1.4**	**1.9**	**2.5**	**3.1**	**3.8**	**4.7**
16-in.	V. C.	**27**	**21**							**1** 35.6 3024	**1.3**	**1.7**	**2.2**	**2.9**	**3.4**
18-in.	V. C.	**20**	**16**	**12**							**1** 36.8 4032	**1.3**	**1.7**	**2.1**	**2.5**
20-in.	V. C.	**16**	**12**	**8.9**	**6.4**							**1** 38.8 5184	**1.3**	**1.6**	**1.[illegible]**
22-in.	V. C.	**12**	**9.4**	**7**	**5**	**3.4**							**1** 40.6 6480	**1.2**	**1.5**
24-in.	V. C.	**9.9**	**7.6**	**5.7**	**4.1**	**2.7**	**1.7**							**1** 42.4 8208	**1.2**
26-in.	V. C.	**8.1** 67 80640	**6.2** 63 6 61920	**4.7** 61.0 46080	**3.3** 56.0 33120	**2.2** 52.0 2304[illegible]	**1.4** 47.4 1425[illegible]	**1.2** 46.0 11952							**1** 44.2 9936
Branches / Diameter of mains		**60-in.**	**54-in.**	**48-in.**	**42-in.**	**36-in.**	**30-in.**	**28-in.**							

pipes of other shapes. It is divided into 20 spaces each way, the spaces between each pair of horizontal lines representing 5 per cent.,—read in percentage of the shorter side to that of the longer.

In contrasting the carrying capacity of rectangular pipes of any given dimensions other than square with that of round pipes of similar area, the percentage of the short side (width) to that of the long is first found at the left. Then trace horizontally to the right until it intercepts the *curve*; this point indicates, by the vertical percentage lines, the per

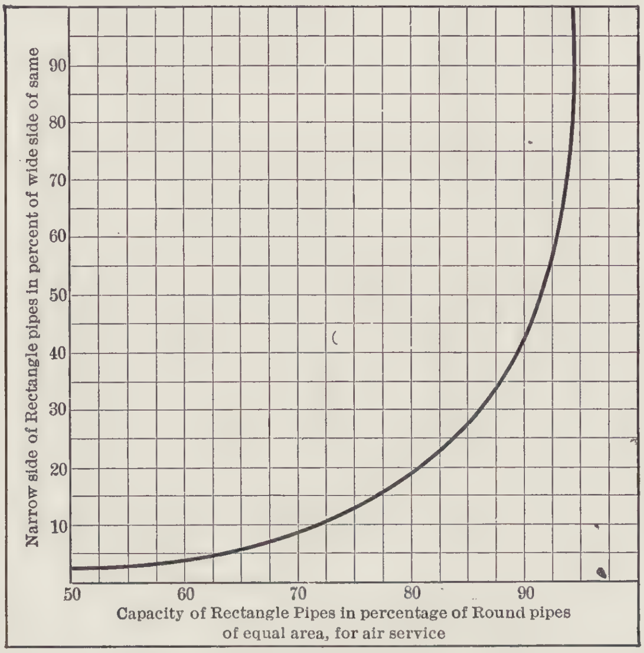


FIG. 305. CHART OF RELATIVE CAPACITIES OF ROUND AND RECTANGULAR AIR PIPES

cent. capacity of a pipe of the dimensions used as compared with that of a round pipe of equal area, and may be read at a glance by the aid of the figures along the bottom of the chart.

The relative carriage of rectangular ducts, may likewise be compared, almost by simple inspection,—the square pipe (while only 94 per cent. that of a circular pipe of equal area) being taken as 100 per cent. when other rectangular shapes are compared with it. Contrasted with the delivery of a round pipe the short side of a $3\frac{1}{2}\times41$-in. pipe (about 144 sq. in. area) is $8\frac{1}{2}$ per cent. of the wide side,—the diagram shows 69 per cent. capacity; 6×24-in. (equal 144 sq. in.) equals 84 per cent., and 8×18, (144 sq. in.) the short side of which is 44.4 per cent. of the long side, develops 90 per cent. of the capacity of a round pipe.

A diagram may not always be at hand, and should it be necessary or desired to figure such capacities, the following will aid,—observing

the rule first given: For comparison, a circle 13.54 in. diameter, and, rectangular pipes 6×24, 4×36 and 12×12 in. are all of 144 sq. in. sectional area. Now, contrasting the rectangular with the round: The square root of the circumference of a 13.54 in. circle, taken as 42.6, is 6.52; continuing according to the rule, 6.52 divided by 42.6 = 0.153. The perimeter of a 12-in. square pipe is 48; the square root of 48 is 6.93. 6.93 divided by 48.0 = 0.144, something less than found for the circle. Now, as 0.153 for the circular pipe is the square root of its circumference divided by that circumference, and, 0.144 for the square pipe is the square root of its perimeter divided by that perimeter, the relative capacity of the two pipes is as 0.144 is to 0.153,—that is as 0.94 per cent. is to 1.0. The other shapes treated likewise show the square root of the perimeter divided by the perimeter to be: for 6×24, 0.129, and for 4×36, 0.112,—compared to the round, 73 per cent. for the latter and 84 per cent. for the former.

There is still another way of approximating the relative capacity of rectangular shapes, quickly applied and easily remembered. The carrying capacity of pipes other than round diminish from the capacity of the round of equal area about one per cent. for each inch of excess of perimeter over the circumference of the round. As an example, an 8×18-in. duct has a perimeter of 52 in. and an area of 144 sq. in.: A circle 13.54 in. diameter has 42.6 in. circumference; the excess of rectangle perimeter over circumference of the circle is 9.4, while the capacity of the 8×18-in. may be taken as 90 per cent. of the equal area circle—practically one per cent., per inch excess of perimeter. In practice, adding one-half of one per cent. to each of the multiplying factors of rectangular shapes for each one per cent. the perimeter of the shape required exceeds circumference of equal area seems to allow for all friction due to excess of perimeter, common fittings, etc., included. Example: A circular pipe of one square foot area is to be changed to a rectangular section to lie in a channel 10 in. deep. What dimensions will give equal capacity? The diameter of the round is 13.54 in.,—circumference, 42.6. An equal area in rectangular shape approximating the required narrow side is 8×18. The perimeter of 8×18 = 52. 52 exceeds 42.6 by 22 per cent. $\frac{1}{2}$ per cent. for each one per cent. of excess of perimeter over circumference equals 11 per cent. to be added to one greater and one lesser side, thus increasing the multiplying elements to offset the retardation of extra frictional surface of rectangular over round shape. To find the actual width of narrow side: one per cent. of 8. = .08; .08×11 = 0.88; 0.88+8 = 8.88, true width, say, of narrow side. For the wide side: one per cent. of 18 = 0.18; 0.18×11 = 1.98; 1.98+18.0 = 19.98, the wide side. Then 8.88×19.98 = 178 an area equal to the area of a 15-in. circle, while the perimeter of the initial dimensions that were added to (8×18) exceeds that of the round 9.4 in.

CHAPTER LXIV

Soil Pipe and Fittings

Were it not that two and four-inch soil pipe, together, make up about 90 per cent. of all soil and waste pipe work, the working stock for a shop would be a serious problem, especially in locations where a supply house cannot be reached in an hour. Of the fittings, less than 100 kinds and sizes out of about 2000 make practically the whole list in general use, yet the others have a well defined purpose though not many out of the usual run are likely to be unexpectedly called for. It is these facts that have helped to balk the strenuous endeavors of some gentlemen interested in standardizing soil pipe and fittings. Specified, some of the reasons why standardization has failed are: 2 and 4-in. pipe, fittings and their hubs are, all things considered, very satisfactory; it was to these that the balance of the outfit was built; if the larger sizes are not all that could be desired, their use is at least limited; the good points of all styles of hubs cannot be embodied in one hub; a desirable feature in one design must be sacrificed in order to secure that most valuable in another; there are numerous makers of these goods; the style of hubs made belong to six different classes; every class of hub is available to every user; fittings of different radii and varying depth of hub are a distinct advantage in meeting the requirements of general work (since work with all these different styles of hub has been installed); changing from a variety to a standard, where dies and machinery for installation are not required, does not give the benefit generally derived from standardization and therefore there is not, with soil pipe, the reason to strive for a standard to succeed variety that there would be to maintain a standard against variety in this line, nor is there the cause in this line to supplant variety with a standard, such as would be evident on one score or another in any other line of goods. Makers have generally voiced their opposition to standardization with the statement that the sizes most used would at most be little bettered and the cost of standardizing the whole line would be out of all proportion to the benefit to be derived.

Of the sketches in Fig. 310, **A** and **B** are sectional views of extra heavy and standard hubs representing in about half size the average 4-in. market pipe hubs; **C** and **D** are the corresponding sizes of a proposed standard. To prevent all chance of slipping out, by the hub pulling off of the lead, **A** and **B** must be supported from bottom of stack; this would mean, practically, hooking in, or otherwise supporting every length; any considerable slippage must take place between the lead and hub; the angle of drift faces at bottom of factory ends is so little that it is

easy to drift the spigot out of center when yarning; with an evenly cut end, the angle of surfaces is acute enough to hold the spigot concentric with the hub.

The strength of an extra heavy market hub, as compared to the strain of calking, under the severest practical conditions is about as follows: Tensile strength of cast iron with the skin on, per square inch, 22000 lb.; lead resistance to compression, say, 2000 lb. per sq. in.; hub circumference of 4-in. 17.3-in.; area of lead calked into contact to average the equal of the force of compression, 3.46-sq. in. (0.2×17.3); $3.46 \times 2000 = 6920$ lb.; sectional area of hub on one side to half depth, including the lead, equals 0.43 sq. in.; $0.43 \times 22000 = 9640$ lb.; $9640 - 6920 = 2720$,—about 40 per cent. margin over the strain tending to split the hub at some point in the circumference of its weakest end; this is considering only half of the total metal resisting the split. So while there is little danger of splitting extra heavy hubs by ordinary calking, every plumber knows that exceeding care is necessary with the average standard pipe to avoid splitting the hub. However, with first class pipe, the author has calked together, on skids, horizontal, 55 ft. of standard pipe, and then suspended it at the center in order to lift it into place, after which it stood the water test. This shows that a good grade of standard pipe is heavy enough for ordinary purposes if erected by an intelligent workman.

The author is opposed to the senseless use of extra heavy pipe in cottage work; the joint is the weak point and good work on standard pipe will make it safe for all requirements, up to three stories high, at least. To legislate into universal use, a hub (and pipe wall) so heavy that ignorance and carelessness cannot split the hub is not only an imposition on the house owner but is an insult to the intelligent element of the trade and a detriment to the whole calling in many ways. Those who have stood for standardizing have not the useless waste of metal in view. This is shown by the section **C** and **D** and, it is to the credit of every one who has recommended a standard, regardless of the merits of the whole matter, that a bettering of general conditions has always been the object in view. The hubs shown by **C** and **D** have a distinct advantage in that very little slippage is possible; the V-channel in the hub prevents the hub from shipping off of the lead; the spigot cannot slip out of the lead; the lead being carried by the hub when slippage begins, the thicker part of the ring of lead (supposing the lead to be deep enough to cover some of the swell on the spigot end) quickly binds on the increasing diameter of the spigot,—in this way the joint, through its circular wedges (one lead and one iron) is self-packing; so, during whatever slippage that at times may take place, the lead cannot work up and the chances of leakage are not so increased. The angles of the spigot

end and hub-offset agreeing and being at the steep angle shown, calking does not easily drift the spigot end out of center.

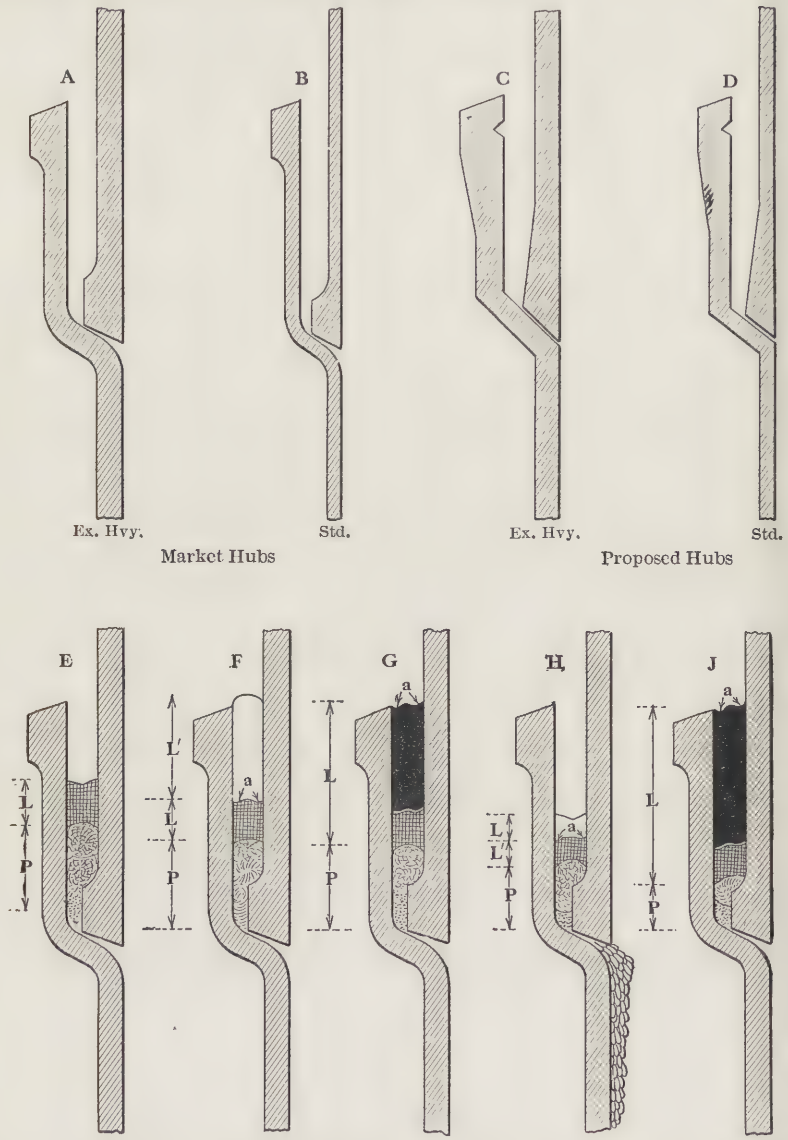


FIG. 310. METHODS AND STAGES OF SOIL PIPE JOINT MAKING AND HUB STANDARDS—SECTIONAL VIEWS

Extra heavy pipe may be reckoned as having a $\frac{1}{4}$-in. wall; standard pipe as having $\frac{1}{8}$-in. wall, and medium pipe as having a thickness the mean between standard and extra heavy, with hubs practically the same as those on standard pipe. Good standard pipe is tested at the factory

to 50 lb. per square inch water pressure before being tarred. Therefore, there need be no hesitation about running standard weight stacks 115 ft. high, and testing same by filling with water.

In small sizes, the strain from handling sections "made up" before placing in permanent position is more in the line of compressing the lead and splitting the hub. With the larger sizes, any strain tending to throw the lengths out of alignment does more toward stripping the joint out of the hub.

Two and 4-in. diameter, need as great depth of hub as the larger sizes, not only for general strength, thickness and permanence of alignment, in place, but because these sizes are more often handled "made-up." Large sizes are put in place before any joints are made up and are usually placed so as to be almost independent of joints, so far as support is concerned.

For vertical joints on work where the strain will be rather severe the author drives in well twisted yarn to the depth of $\frac{3}{4}$ to $\frac{7}{8}$-in., letting the beginning of the yarn taper down to nothing in about 6-in. and the length of the whole piece be such that with another tapering end at the finish the yarning depth will be of even depth all around. A ring of lead is then poured $\frac{1}{2}$ to $\frac{3}{4}$ in. deep hot enough to make it unite where it meets; this is next calked down while warm, thus driving the packing into place more firmly, spreading the lead to counteract the shrinkage, giving it more side bearing and a better bottom seating. If the lead is not very hot or the pipe is large, the ladle can be moved around the hub while making the first pouring, so the metal will not have to flow far to meet and unite with that traveling around the pipe in the opposite direction. After the first or preliminary pouring is calked down the packing and lead together are 1-in. to $1\frac{1}{4}$-in. deep; the balance of the hub is then filled at one pouring and settled down with the calking tool while warm; after the joint has cooled somewhat the lead is tamped up more solidly and the edged peened to both the hub and spigot surfaces. All this is illustrated in sketches **H** and **J**,—**P**, in sketch **H**, being the depth of yarning; **L′** plus **L** the depth of uncalked first pouring; the dividing line between **L′** and **L**, the level of first pouring after it is driven down,—**a** showing the depressed lead surface next to the iron walls due to tamping and pinching the lead into contact with the iron with a thin calking tool (a short blade yarning chisel is generally best for this purpose); **J** is a section of the finished joint, in which **P** is the depth of fully calked yarn; **L** the full depth of lead; **a**, face of joint peened to the iron as before mentioned, after tamping down reasonably tight. The dotted line is the point where the two pourings join. By pouring fast in one place, the two pourings will weld together part of the way; if the lead is very hot and a large ladle is used, it may weld all around; such welding of the two pourings is not necessary. For large joints the pot

or ladle should be moved around the pipe while pouring, until the lead meets and unites.

Pouring and calking a preliminary ring of lead on the packing gives a hard solid bottom to pour the balance of the joint on, insures no serious "burning through" and gains resistance to prevent the lead of the final pouring from driving down. The final pouring thus finds a better bearing and settles into contact with the iron surfaces better and with less danger of cracking the hub than when the whole joint is poured at once from the packing up. Further, with a preliminary calking at the bottom a much safer joint is made than it is possible to make by pouring the whole joint at once and calking it only at the top, because, while a ring of lead the whole depth may be driven down some, it cannot be spread and hardened with any good effect to even one quarter of the distance from the top. A joint made at one pouring is, on light soil pipe, therefore, easily shifted just as a fence-post is easily wiggled in the hole when the dirt has been rammed at the top only,—both being unstable because the filling offers little resistance at the bottom.

It should be remembered that the hub of a soil pipe is expanded from the heat of the lead just after pouring and that it will contract to its former size or split when it cools off. For this reason it will not do to calk the face of a soil pipe joint too quick after the lead "sets,"—wait until spittle on the lead will not fry or make vapor freely.

If a joint space is thinner than ordinary, as it sometimes is, due to using pipe and fittings of different makes together, one need not hesitate to fill practically the whole hub with lead,—making two pourings, if there is room to calk the first. A bead of glazier's putty can be pinched to the hub offset, or to the spigot end, to keep lead from running through, if the space is too narrow to yarn up in the regular way.

If a leak is feared in any case, soak the yarn in linseed or other oil, or scrape some shavings of candle in on top of the yarn on first pouring. It is not a bad idea to use oiled yarn regularly, as it repells water and prevents moisture from swelling the packing too tight.

Sketches **E**, **F** and **G** show the same stages of making a soil pipe joint as described for **H** and **J**; the letters in all the sketches refer to corresponding parts. The difference in the two joints, **G** and **J**, is the extra packing and less lead used in **G**. Joint **G** is suitable for vent, leader and other lines in locations where the joints need not to be the best possible.

It is not practicable to run a good horizontal or inclined joint except by pouring the whole joint at once. If the weight at the spigot end of such joints makes it difficult to yarn up on account of the yarn compressing at the bottom of the lead space and thus making the space markedly uneven, so the lead will not be thick enough at the bottom and too thick at the top, try first, hemp twisted extra hard and well

driven up. If this will not keep the spigot end concentric with the bell, a ring of cold strip sheet-lead may be driven in and calked up to even the space. This is equivalent to the preliminary pouring before mentioned and while insuring a joint ring of uniform thickness it provides a degree of rigidity and tightness of the finished joint that may be depended upon unless more than normal weight or strain is left upon the joint.

Where the character of vertical joints is not important a second yarning $\frac{3}{4}$ in. deep when driven hard down may be put in on top of the preliminary pouring of lead and a final pouring calked in on top of it to finish out the joint. This plan of using a hemp middle filling is well enough if good judgment is used in deciding which joints it would be safe to so make; however, the tendency is to scrimp work and to generalize the practice when it is permitted at all at the discretion of ordinary workmen.

For yarning, there is no better material for general use than a good grade of twisted hemp, because its thickness in the strand is a good guide to the thickness of packing it will make in place; it is easy to measure for circumference and the necessary laps, and it fills all other requisites.

A safe flexible, permanent soil pipe joint may be made without using metallic lead at all. The author has installed many vent and leader stacks, and thousands of feet of soil pipe for heating work without using an ounce of metallic lead or resorting to rust joints. Some of the work has been in service twenty-five years without a leak and many of the joints so made, have been continuously under a water pressure of from 3 to 10 lbs. These joints were made with a good grade of well twisted hemp, soaked in boiled linseed (Ky. flaxseed) oil in which some dry red lead had been well stirred. The hemp strands were dipped and rung out by hand to a reasonably dry state before calking in. A joint made in this way with the hemp well driven in to fill to within $\frac{1}{4}$ to $\frac{3}{8}$ in. of the face of the hub, and the joint-space then filled to the face with a stiff red lead putty, made of red lead mixed with boiled linseed oil, is better than a metallic lead joint yarned and calked in the usual way, unless there is a strain tending to pull the joint apart endwise.

From 5 in. diameter up, in any but the joints of vertical stacks, the regular metallic lead joints are best made as nearly all-lead as the position and circumstances will permit.

For estimating freight, either when purchasing from distance points, or to get the freight item for a job out of the home town, the approximate weight of all staple fittings and pipe from 2 to 8-in. diameter are given in the Table XXVI, herewith.

Soil pipe and fittings being shipped "loose," no crated weight is necessary. For estimating purposes, reducing sizes can be taken at the weight of straight sizes, as in the small branch openings, more metal

goes into the main wall of the fittings, because the branch hole is small, and for the same reason there is less metal in the hub and neck of the small branch than in the same of the straight sizes. There variations by no means balance each other, but the straight weights will do for freight purposes.

Table XXVI. Approximate Weight of Standard and Extra Heavy Soil Pipe and Fittings. Fittings, Pounds Each, Standard in Light, Extra Heavy in Heavy Figures

Pipe Size, inches	2		3		4	
Pipe, per foot	$3\frac{1}{2}$	**$5\frac{1}{2}$**	$4\frac{1}{2}$	**$9\frac{1}{2}$**	$6\frac{1}{2}$	13
$\frac{1}{4}$-bends	4	**6**	$5\frac{1}{2}$	**8**	8	**12**
$\frac{1}{6}$-bends	3	**$4\frac{3}{4}$**	$4\frac{3}{4}$	**$6\frac{1}{4}$**	6	**$9\frac{1}{2}$**
$\frac{1}{8}$-bends	3	**$4\frac{3}{4}$**	$4\frac{3}{4}$	**$6\frac{1}{4}$**	6	**$9\frac{1}{2}$**
Tees	4	**7**	8	**13**	10	**20**
Crosses	5	**10**	10	**20**	12	**24**
Y-branches	5	**10**	9	**15**	13	**25**
$\frac{1}{2}$ Y-branches	$4\frac{1}{2}$	**9**	$6\frac{1}{2}$	**13**	10	**18**
Double Y-branches	8	**12**	11	**20**	18	**32**
Double hubs	3	**$4\frac{1}{2}$**	4	**7**	6	**8**
Straight sleeves	$2\frac{1}{2}$	**4**	4	**6**	5	**7**
Traps	$5\frac{1}{2}$	**9**	10	**18**	19	**28**
Reducers	—	—	3	**4**	4	**6**

Pipe Size, inches	5		6		8	
Pipe, per foot	$8\frac{1}{2}$	**17**	$10\frac{1}{2}$	**20**	18	**$33\frac{1}{2}$**
$\frac{1}{4}$-bends	10	**15**	$14\frac{1}{2}$	**20**	34	**44**
$\frac{1}{6}$-bends	8	**12**	11	**16**	24	**$35\frac{1}{2}$**
$\frac{1}{8}$-bends	8	**12**	11	**16**	24	**$35\frac{1}{2}$**
Tees	15	**25**	20	**34**	38	**50**
Crosses	16	**32**	24	**48**	43	**85**
Y-branches	18	**32**	25	**45**	42	**85**
$\frac{1}{2}$ Y-branches	14	**24**	16	**30**	25	**55**
Double Y-branches	26	**42**	37	**60**	80	**110**
Double hubs	8	**11**	10	**14**	16	**28**
Straight sleeves	6	**9**	7	**15**	12	**22**
Traps	26	**45**	35	**68**	58	**102**
Reducers	6	**8**	8	**11**	9	**16**

Offsets, size and offset	2x8	3x8	4x8	5x8	6x8
Standard, lbs. each	5	8	11	15	22
Extra heavy, lbs. each	**9**	**15**	**17**	**23**	**38**

Single hub pipe is 5 ft. long without counting hub. Double hub pipe is 5 ft. long plus one hub. Take weight of red fittings to be same as straight sizes given.

Note—Soil pipe and fittings, not tarred, are frequently used for Greenhouse Heating Surface.

One degree ($\frac{1}{4}$-in.) or less fall per foot horizontal runs will answer if but little pitch is available; it is a good rule, however, to give all the pitch or fall that the space will allow.

With a 30-deg. Y, one 30-deg. bend ($\frac{1}{12}$) gets back to the vertical, and two 30-deg. bends or one 60 deg. ($\frac{1}{6}$) gives the horizontal. One 45-deg. bend ($\frac{1}{8}$) with a 30-deg. Y, gives an incline up of 15 deg. from the horizontal. With a 60-deg. Y, one 60-deg. bend reassumes the vertical; one 30-deg. bend reaches the horizontal, and one $22\frac{1}{2}$-deg. ($\frac{1}{16}$) gives $7\frac{1}{2}$ deg. incline up from the horizontal.

CHAPTER LXV

Wrought Pipe Drainage

There has been well directed and quite effective opposition to wrought pipe for drainage purposes from the time it was employed, frequently enough to suggest that it might become a serious competitor of cast soil pipe. There was probably never more good reason to oppose it than accompanies the hue and cry raised against any other innovation,—cast iron soil pipe survived strong opposition from expert lead workers throughout its introduction. Wrought pipe will finally take its place according to its merit, not as *the* pipe for the purposes, but judged without prejudice and used, or not, in keeping with its suitableness for the particular job in hand. Cast iron is the better material in point of ease in handling and installing, low cost and known longevity of service. Unless there is abrasion to remove it, a coat of oxide forms and remains on cast pipe, as a protection against further corrosion. From two to four centuries of service in earth are of record to the credit of cast pipe; it was the permanence of plain cast surface that kept enameled and galvanized cast iron soil pipe from finding a general market. In the matter of joints and support it is, however, very inferior to wrought pipe, much as was the old hand-made lead stacks when compared to cast pipe. Well made calked joints will live out the life of the majority of structures, if the pipe is thoroughly supported, and cast pipe with hub and spigot joints can be rusted together so as to make the whole system practically one piece of pipe, but while a few rust joints are made here and there, such will never amount to more than rare exceptions, because there is no flexibility to such work and it is also difficult to repair or change, or to replace cracked hubs likely to result in new work from expansion of the rust in joints packed too tight.

Wrought drainage and vent pipe will rust and scale off repeatedly in damp locations, especially where exposed to extremes of temperature, vibration, abrasion, or corroding vapors. Some plain pipe jobs have, nevertheless, seen a quarter of a century of service under ordinary conditions without appreciable deterioration. How much longer they will stand no one knows, but there has been no hesitation about installing plain wrought drainage in buildings costing millions of dollars. Galvanized wrought pipe and fittings are used in the drainage and vent work of many good jobs, especially in tall buildings where room is at a premium and strength and rigidity of joint more essential. High stacks in wall supported buildings require some provision for expansion, which may be taken care of by providing fall in the laterals to permit enough spring

and swing at the turn-outs to them to follow the stack travel without rupture or interference with the drainage. Some tall building work has been done on the "continuous" plan, partly for the purpose of cutting up the expansion into story lengths, thus making it a negligible quantity.

Wrought drainage fittings are made of cast iron, plain and galvanized, in both long sweep and in ordinary (steam-fitting) radius. The short radius fittings are common in drainage lines and are generally used for vent work. All of these fittings differ from ordinary steam and water fittings in that the ends are recessed and threaded in the recess, as shown in Fig. 312, so as to make the interior diameter of the fitting the same as that of the pipe used with them, thus presenting no pipe ends to retard the flow of the contents and no place for paper or foreign matter to lodge in a way to obstruct the pipe. Fittings with brass clean-out screws or plugs are a feature of this line of fittings, and ample means for cleaning lines in place through such openings are usual to wrought pipe jobs in the better class of work.

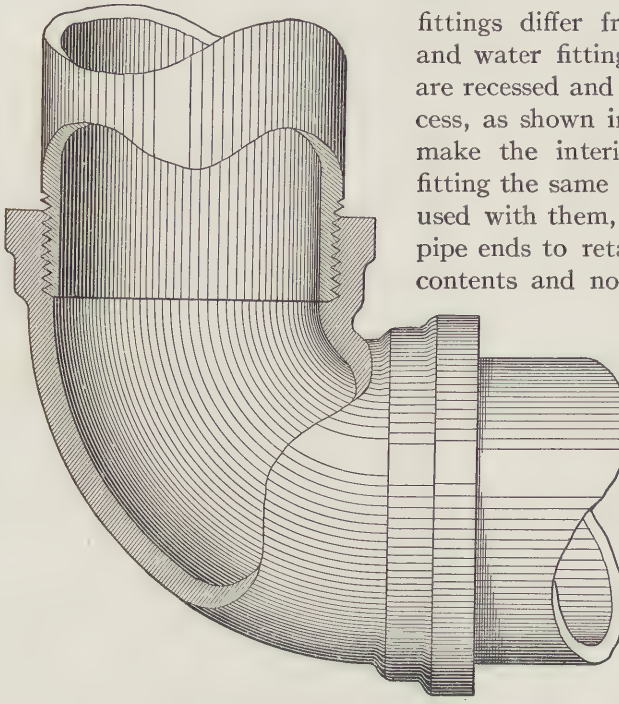


FIG. 312. RECESSED ELBOW

Drainage bends are made regular in 90, 60, 45, 30, $22\frac{1}{2}$, $11\frac{1}{4}$ and $5\frac{5}{8}$ deg.,—the latter angle being $\frac{1}{16}$ of the bend in a common 90 deg. elbow. It is well to mention that the $5\frac{5}{8}$-deg. bend is often called a *one-sixteenth bend*,—$\frac{1}{16}$ of the 90 deg. bend is meant, not $\frac{1}{16}$ of the circle as is usual when speaking of soil pipe, $\frac{1}{6}$ and $\frac{1}{8}$ bends, etc. Recessed end tees for use in vertical lines are tapped 1 deg. acute with the receiving end,—this gives the lateral about 0.2-in. rise per foot. In order to give the fixture or high end of laterals a vertical branch, "pitched" branch fittings and ells are made, the ells being tapped 1 deg. obtuse,—that is, 91 deg. are included in the tapping angle. Of course, laterals can be given the required "pitch" by cutting "crooked" threads, but it is expensive in time and no boy's job, even for a few threads, because, both threads of a lateral have to be cut "crooked" and pitched equally

in opposite directions. This is not easy to do in the machine, is difficult to do with the stocks, and generally the pipe runs in sizes as large as any one cares to cut straight work on,—hence the "pitch" fittings.

Hood sockets for flashing work, reducing sanitary basin waste tees and crosses, closet ells, return bends, traps, transition fittings for changing from iron to lead at fixture ends, etc., are made to meet every requisite of using wrought pipe in place of cast soil and waste. Makers' catalogues will be found replete with sizes, weights, and much commonplace data essential to use of the goods, but too tedious to review here. Y-fittings with either 60 or 30-deg. branches are regular stock; the fractional bends are used with these to reach a vertical or horizontal course, just as $\frac{1}{8}$ and other bends are so used in hub and spigot joint work, except that with threaded joints, there is no chance to change the pitch of a lateral, from standard, in the joint, except by swing joint, unless crooked threads are cut for the purpose, though it can be swung to right or left. Therefore, precise measurements must be taken from definite points and the pipe carefully cut and fitted to conform, just as in steam and hot water work. With cast pipe and lead joints, great latitude in fall and in position of ends is available in setting the joints and the greatest care necessary is to set and run them with the pipe and fittings in just the relation desired, especially in work where it is advantageous to make up considerable chunks of pipe and fittings on the floor or ground and then hoist the whole into permanent position and there make one joint in place instead of many. With wrought pipe the joints are all similar, reasonably certain of being perfect and tight, and the angles are definite and beyond altering at will, so, not only must measuring and fitting be skilfully done, but there is frequently room for keen judgment and foresight in providing room and means to screw up large heavy fittings in the midst of beams and other structural interferences that cannot be moved and either cannot or must not be cut. Time may be saved in some instances by making up a portion of a stack with a number of fittings attached and setting it into place where fittings could not be screwed up regularly, and then building on to the part, so set, at both ends,—commencing in the middle, so to speak.

Fittings with right and left side openings are made with the side holes near the top of the fittings, and also near the bottom, to facilitate running the branch pipes high or low, above or below or between floors. These openings have long been a source of confusion, in both threaded and hub and spigot fittings. A stack is faced by the workman in the building with the branch of the fitting pointing into the building, and by all the logic that can be brought to bear, this brings the *right* and *left* of a tee, or Y-branch to agree with the *right* and *left* of the person, when facing the main branch opening. A fitting has not a personal right and left to aid in designating as though it was a person standing before us.

Makers name these fittings differently,—in one book the engraver has branded *his* right as the right side of the fitting, with the fitting engraved with the back of it facing the person; in another book, it is so branded with the main branch of the fitting facing the person, etc. So, regardless, of what is proper, it is safe, whether right or wrong, to study the engraving of the make of fitting to be ordered, and then order the side openings needed, right or left, according to the catalogue ordered from, and, if ordering from a jobber, name the catalogue from which the rights and lefts were determined.

In connection with recessed fitting work, and cast soil work, too,

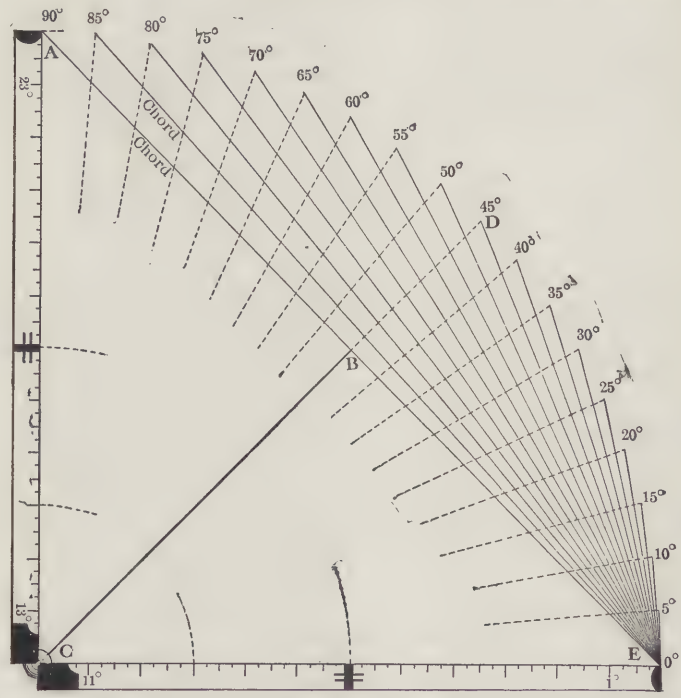


FIG. 313. USE OF COMMON RULE IN DETERMINING DEGREES OF ANGLES

to some extent, one is now and then in doubt either as to the angle of a proposed or necessary pipe course or of that of a fitting at hand,—the latter being mostly true of helpers sent for stock, or of those who do not use such fittings often enough to become familiar with the angles at sight. A simple means of finding degrees of angle, whatever for, is given in Fig. 313, and the Table, XXVII, of chord lengths used with it. A common 2-ft. one or three-joint pocket rule used in conjunction with chord lengths to a radius of one foot for even degrees offers an easy way of finding the degrees included in any angle for which the chord is given, as well as giving some other data needed by the craft. Fig. 313, shows

a rule opened to a right angle,—90 deg.; its chord, **AE**, is the length of the diagonal piece, center to center of fittings, for an offset of 12 in. in a pipe line, using 45-deg. fittings; the length of the piece in inches, decimally expressed, is found in the table in the bottom line under 0,—16.97 in. Half the chord **AE**, as **BE**, makes the diagonal of half this offset, (6 in.), etc. This is not true of any but 45-deg. fittings because the sine and cosine are equal only for an angle of 45 deg. The chords of the diagram advance by intervals of 5 deg. and are drawn in solid line, all beginning at **E** and each ending at a point in the omitted arc from which are dotted the limiting secondary radii, graphically indi-

Table XXVII. Table of Chords for 12-in. Radius, 1-99 Deg.
Deg. of Angle and Chord Lengths in Inches 1 to 99 Deg. with Radius 12 In.

Deg.	0	1	2	3	4	5	6	7	8	9
0–9	0	.2	.42	.63	.84	1.05	1.26	1.47	1.67	1.88
10–19	2.09	2.3	2.51	2.72	2.92	3.13	3.34	3.55	3.75	3.96
20–29	4.17	4.37	4.58	4.78	4.99	5.19	5.4	5.6	5.81	6.01
30–39	6.21	6.41	6.62	6.82	7.02	7.22	7.42	7.61	7.81	8.01
40–49	8.2	8.4	8.6	8.8	8.99	9.18	9.38	9.57	9.76	9.95
50–59	10.14	10.33	10.52	10.71	10.9	11.08	11.27	11.45	11.64	11.82
60–69	12.	12.18	12.36	12.54	12.72	12.9	13.07	13.25	13.42	13.59
70–79	13.77	13.94	14.11	14.28	14.44	14.61	14.78	14.94	15.11	15.27
80–89	15.43	15.59	15.75	15.9	16.06	16.21	16.37	16.52	16.67	16.82
90–99	16.97	17.12	17.26	17.41	17.55	17.7	17.84	17.97	18.11	18.25

cated to aid apprentices in interpreting the figures of the table, which gives the chord lengths 1 to 99 deg., for 12-in. radius, as before stated.

Nine degrees obtuse is sufficient for any call a pipe fitter is likely to have in ordinary work.

The lengths for the first nine degrees are directly under the digits in the top line; for any degree over nine, find the tens of the angle in the extreme left hand figures of the degree column at the left of the table and follow the line to under the units of the angle and there read the chord in inches, thus: for 67 deg. find 60 at the left, fourth line from the bottom; follow to the right on that line to the column in which 7 is found in the line at the top of the table,—13.25 in., the chord, is found there, at the intersection of column 7 with line 60-69.

Now, to apply the pocket rule in finding angles: Open it more or less as required to match the openings of a pipe fitting, tangents of a pipe bend, sides of a corner, pitch of roof with the vertical or level, proposed or necessary pipe course to the level or vertical, or, whatever it may be that the angle of is required; when the rule is set carefully, mark on a board the distance from rule points, **A** to **E**, or measure it with another rule; then find the nearest or corresponding measure in the table and trace the degrees, of angle from the intersection where it appears. If the chord length of any degree is wanted for any radius greater or less than 12 in., divide the table chord by 12 and multiply the

quotient by the inches in the radius of the chord desired; or, if the desired chord is in feet, multiply the chord length given by the number of feet.

Speaking directly of wrought drainage, again, a well established practice of safe-guarding plain wrought vent stacks from choking with corrosion is shown in Fig. 314. At the left **AEB** is an offsetted vent stack,—**A** and **B** being vertical, and **E** about level; **A** is extended a distance **O** below line **E** and then takes, as line **D** the same course as **E**; some one or more fixtures, perhaps a stack of sinks or lavatories, is connected at **F**. If **B** is merely a vent line all the way to the main house sewer line, **C** is connected to **B** anywhere below the offset. If **B**, below the offset, has fixtures connected at some lower point and is purely a vent above those fixtures and the vents of branch waste lines, etc., lead into it above the fixtures, then **C** is carried down to below the fixture level before connecting into **B**. What corrosion forms in **E** is not enough to obstruct it; that which falls in **A**, falls through **O** to **D**; that which forms in or is received by **D** is washed out by fixture water entering at **F**.

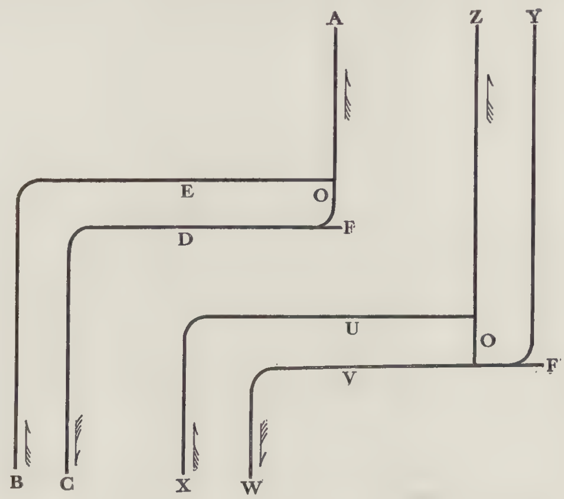


Fig. 314. Protecting Wrought Vents from Choking by Corrosion

At the right in Fig. 314 is shown the connections where both a waste and a vent line offset together, the principle of keeping clear being just the same as already mentioned,—**ZX** and **YW** are extended regularly and the corrosion of the vent is taken care of by the water-washed line.

In the sketches the vent lines (**E** and **U**) are shown as though above the level of the washed lines, **D** and **V**. This may be so if it is convenient, but is not the usual layout. The upper portion of the vent should be directly over the water-washed line,—a vertical continuation of it, from **DF** or **CF**, up. The branch above **O** is taken out at right angles to the stack, and may, if necessary, be turned down as close to the stack as practicable and extended parallel to **O** to bring **E** or **U** line to any level desired. The alternative of thus taking care of plain stacks is to use galvanized pipe,—at least for vents above unwashed offsetted portions.

CHAPTER LXVI

Soil Pipe Systems

There are various methods of installing the soil and waste pipes and their ventilating pipes for plumbing fixtures. In the sketches of Fig. 320 may be seen the main features of the principal systems in use. It would be folly to say that any particular method should be universally used, regardless, but it is well to remember; that every feature of every system was introduced for a reason,—generally a good one; that the agitation in favor of so-called simplification of soil and vent work is largely the work of people who have not given the subject sufficient thought; that simplification to the degree of defeating the object of the work is not improvement,—a fine watch movement can be simplified to a marked degree—at the expense of its general excellence and reliability; that nobody has proven or claims that sewer air is good for the health; that explosive gases have found their way into buildings through untrapped drains; that the safest job is one that keeps sewer air not only out of the rooms of a house but also out of the pipes in the house, and that a house can be piped so as to exclude sewer air from it and its pipes. Until these statements are proven untrue, the author is for the safest job consistent with the prevailing conditions and is willing to a reasonable degree to fit the system to the building it goes into. When they are shown to be false, he will recommend the abandonment of all vents and traps except the back-water trap.

Closure by frost from the freezing of vapor at the upper end of stacks is one point to be taken care of in piping a building. To this end, vents less than 4-in. diameter are increased to at least 4 in. Sometimes several small vents are assembled in the attic and one pipe, 4, 5 or 6-in., extended through the roof. The type of system, kind of building or its use, or the source of vent air may effect the humidity through the amount of surface exposed to house-warmth, per cent. of wet surface in pipe, character and extent of heating in the building, regularity of the heating, and amount of warm water used. The vapor of incoming air must be carried at all hours. Service in some degree generally lessens the chances of frost at the vent end. If the building and system both tend to low humidity the issuing air may be excessively dry; if both favor an increase of moisture the vent air issuing may be saturated.

In estimating the comparative carriage of branch lines, cubic feet capacity, surface, wet and warmed, etc., for rough results, considerable figuring is saved by using the Data of Table XXVIII following:

As a guide to the probable conditions that will ordinarily prevail

during cold weather in the systems shown in Fig. 320, some relative values are given in Table XXIX. The stacks illustrated in Fig. 320 may be classed accordingly

Table XXVIII. Approximate Relative Carrying Capacity, Areas and Surface of Soil Pipes

		8	6	5	4	3	2
Pipe diameter, inches		**8**	**6**	**5**	**4**	**3**	**2**
Linear foot equal to 1 sq. ft. surface		0.44	0.58	0.7	0.85	1.1	1.6
Linear foot holding 1 cu. ft		2.8	5	7	11	20	43
8-in.	Carrying capacity, friction allowed for equals	.....	2.1	3.2	5.7	12	32
	Area equals	.....	2	3	4	7	16
	Circumference equals	.....	.....	.....	2	3	4
6-in.	Carrying capacity, friction allowed for equals	.....	.....	1.6	2.8	5.7	16
	Area equals	.....	.....	.....	2	4	9
	Circumference equals	.....	.....	.....	.....	2	3
5-in.	Carrying capacity, friction allowed for equals	.....	.....	.....	1.8	3.6	9.8
	Area equals	.....	.....	.....	.....	3	6
	Circumference equals	.....	.....	.....	.....	.....	2
4-in.	Carrying capacity, friction allowed for equals	.....	.....	.....	.....	2	5.7
	Area equals	.....	.....	.....	.....	.....	4
	Circumference equals	.....	.....	.....	.....	.....	2
3-in.	Carrying capacity, friction allowed for equals	.....	.....	.....	.....	.....	2.7
	Area equals	.....	.....	.....	.....	.....	2
	Circumference equals	.....	.....	.....	.....	.....	1.5
Cross-sectional area, inside, square inches, equals		50	29	20	12.7	7.4	3.3
Circumference, outside, inches, equals		27.1	21	17.5	14.1	11	7.5

NOTE:—The body of the table gives the aggregate carrying capacity, area and circumference which the sizes at the top are equal to in the sizes given at the left.

Table XXIX. Approximate Relative Humidity and Heating Surface Values of the Stacks Named Below

No.	Temperature of Contents	Temperature Initial air	Temperature Air at Exit	Initial Humidity	Humidity at Exit	Heating Surface	Dry heating Surface
1	Medium	High	Medium	High	High	Small	Small
2	Low	Low	Low	Low	Medium	Small	Small
3	Medium	High	High	High	High	Medium	Great
4	Low	Low	Medium	Low	Medium	Medium	Great
5	Medium	High	Medium	High	High	Great	Small
6	Medium	High	High	High	Medium	Great	Great
7	Medium	Low	Medium	Low	Medium	Great	Great

No. 1—Plain soil and vent stack,—air from sewer.
No. 2—Same as No. 1, with intercepting trap,—air from atmosphere.
No. 3—Plain loop stack,—air from sewer.
No. 4—Same as No. 3, with intercepting trap,—air from atmosphere.
No. 5—"Continuous" stack,—air from sewer.
No. 6—Same as No. 5, with dry vent,—air from sewer.
No. 7—Same as No. 5, with dry vent and intercepting trap,—air from atmosphere.

The principal features of the stacks in Fig. 320 are: No. 1 ventilates the public sewer through the house line; keeps the pipes filled with sewer

air and whatever it contains; favors high humidity and closure of vent by frost in winter; leaks or unsealed traps turn undiluted sewer air into the house; the discharge of fixtures reverses the current and brings air in at the roof (possibly syphons upper traps) and drives air in front of the discharge water, sometimes strong enough to unseal lower traps; if the sewer floods during a rain storm, common trap seals of lower fixtures

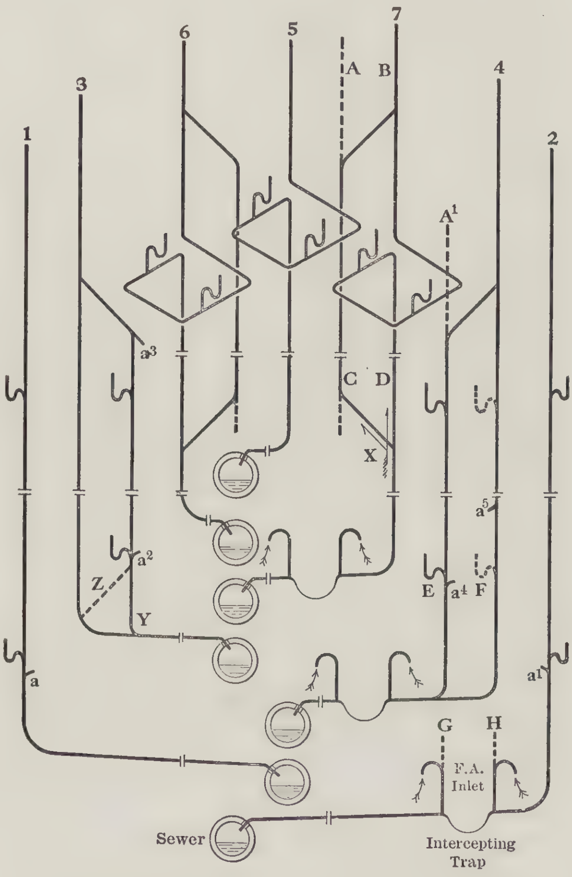


FIG. 320. FEATURES OF VARIOUS SOIL PIPE SYSTEMS

may be "spouted" out by discharges from upper fixtures,—because no relief for trapped air is provided. If there are fixtures some distance from the main stack, branch lines are run, as, say from **a**, **a**^{1}, **a**^{2} and **a**^{4}, and the branch vented, either back into the stack like at **a**^{3} No. 3, above the highest fixture and into the dry line, as at **a**^{5} No. 4, or to the roof independent of the stack.

Through the agency of an *intercepting trap*, *fresh air inlet* and *foul air outlet* stack No. 2, which would otherwise be the same as No. 1,

operates as follows: the public sewer is ventilated independently; no sewer air gets into the building; no dangerous vapors of gasoline, kerosene, etc., nor coal gas or other lighting gases, can reach the house system, which is kept filled with air direct from the atmosphere; fixture discharges may reverse the current, or syphon traps as before mentioned; air in front of discharge water cannot affect the seal of lower traps; some foul air may be puffed out at the *fresh-air inlet*,—if it is short; humidity is always less than with No. 1, if other things are equal. The trap may be in the yard or in the cellar; the air inlet and outlet should rise vertically as far as possible or consistent with conditions and the position of trap,—their ends should not terminate close together; either or both may be piped to the roof as from **G** and **H** in the sketch, if necessary; if the trap is near a door or window the inlet should be piped some distance, so air driven out by fixture discharges will not be offensive,—the extra length incidentally insures that *fresh* air will be expelled, so a long inlet may terminate near a door or window if necessary, it is best to turn all inlets down, as shown.

A "loop" stack is represented by No. 3. In it the current is not reversed in the vent stack portion by fixture discharges and no chance of unsealing either upper or lower traps occurs. The current is not necessarily reversed anywhere at any time, except in the fixture stack portion of the loop. Humidity, other things being equal, is higher than in No. 2, and lower than in No. 1, due to the extra heating surface and the large volume of the air going up the "dry" stack. A fixture discharge causes air going up the dry stack to turn down the fixture line and prevent vacuum behind the water; air in front of the water turns up the dry stack to supply its extra call for air. The result from discharging a fixture is merely a revolution of the air in the loop without consequence to the traps and generally without producing any change at the terminals of the system. In practice, the wet line should connect to the dry stack, as indicated by dotted line **Z**, instead of going into the horizontal run. If the fixtures were connected to what is shown as the dry line, then the connection at **Y** would be proper because it would serve as a dry line.

The object should be, in every case, with any system, to take as much of the vent air as possible up the dry line; to provide crown trap vents (if there are such) with humid air,—piped from vent extensions of branch waste lines, and to arrange for a direct fall of foreign matter in the vents to a point where it will be washed out by fixture water.

No. 4 stack is essentially the same as No. 3, with the intercepting trap and its connections added. Taking the air from the atmosphere instead of the sewer, the vapor leaving the vent is reduced below that for No. 3. In practice the wet line might also be extended to the roof as indicated by $\mathbf{A}^1$,—depending, if there is occasion, upon the kind of

traps or how they are vented. Where the wet line goes to the roof separately, the traps should have crown vents or otherwise the traps should be of the non-syphoning type. A further feature of actual work would be the placing of the fixtures on what is shown to be the dry line; this is indicated by dotting the traps at **F** as a more desirable position than at **E**.

The stack shown by No. 5 is termed "continuous." Like No. 1 and No. 2, it combines the vent and fixture stack into one line. Stacks like No. 5 are understood to be and referred to as "continuous" in more than one sense, thus causing some confusion in statements. Nos. 1, 3, 5 and 6 are "continuous" in the sense of providing an unbroken way for sewer air to reach the roof through the house system,—no trap being provided for the house sewer. In the more usual sense No. 5 is a "continuous" stack winding about in a way to take the discharge from all fixtures, (through short connections) or at least, of as many fixtures as can be so reached without going to more expense than 2 stacks would cost. This method is often employed through the mistaken notion that a trap with a short branch connection, 3 ft. or less, will not syphon and that therefore it would not be necessary to vent common traps, nor, if we take actual practice in some localities as a guide, to be even so cautious as to use non-syphoning traps. Some tall buildings have been so piped, at a needless outlay for large pipe and fittings.

No. 6 is the same as No. 5, with a dry line added. The dry line adds heating surface and lowers the humidity of the air at the exit, in addition to giving the advantages of the loop, mentioned in connection with No. 3. In practice the dry line of No. 6 would be run down to the horizontal part, or, what is shown as the dry line would perhaps be made the wet line.

No. 7 differs from No. 6 in having the intercepting trap and its connections. In practice the wet line would be **C** instead of **D**, or **C** would connect straight down, giving it a better chance to keep itself clear, and also the opportunity to carry more of the air to the roof. **C** could be extended through the roof separately as indicated by **A**, but so doing would increase the effective humidity in **B**. In all branches, the air divides, as shown by arrow at **X**. The branch should always be made to favor the dry line with the greater air travel.

CHAPTER LXVII

A Loop Stack Soil and Waste System

In Fig. 325 is shown the most efficient stack arrangement for use with or without an intercepting trap and fresh air inlet. The trap is placed in the main house line, inside or outside. The foul air inlet (**O**), relieving the sewer line up to the trap, may terminate anywhere above snow level,—above the roof if necessary, but should not end very close to the fresh air inlet (**I**). If the trap is near to or within the house, the fresh air branch may need to be given more than the length merely necessary to reach outside the wall or up to the surface, in order that in case the current in it is reversed by fixture discharges no foul air will be puffed out. It is partly the purpose of a loop stack to prevent reversing the current at any point other than in the water-fall portion of stack **B**, though reversals may occur in the main lateral between the trap and stack connection, especially if the lateral part of the main run is the same size as the stack.

The heaviest possible waterfall in stack **B** can do no more than produce a revolution of the air contained in **A** and **B**,—just as intended, the air turning down **B** from **A** at the top junction and up **A** from **B** at the bottom. In this way no pressure is created on trap seals below falling water and no vacuum can form to disturb the seals of traps above the water falling. If, by a discharge, some tendency to lower pressure is created in laterals leading to **B**, it is counteracted by the plenum in the branch vents, for they are connected to **A** through which air is being supplied to maintain an equilibrium behind the falling water and are thus a means of preserving normal air pressure in the branch pipes **a′**, **h**, etc. It was to secure this action, that branch vent line **b′** was connected to **A** instead of to **B**.

It is the function of the air inlet to keep the air in the entire house system of soil, waste and vent pipes as pure as atmospheric air can so make it. This being the case, the least possible damage will result from leaks, traps unsealed from disuse or any other abnormal condition, no matter how it comes about.

The traps of kitchen and pantry sinks should be larger than the bore of the outlet nipple. No syphonage is then likely to occur when traps, not vented at the crown, are connected close and at the outlet-leg level, as shown. When the sink discharges, air behind the water is supplied through **b** and down through the fixture upright **c**, it following the water to the stack through **a**, if the call for air is sufficient. The action through the bath room branches is similar.

The fixture at the end of a branch waste should be taken from the extreme end, as at **h**, in order to water-wash the whole lateral. If pipe **f** was taken from **h** and the trap waste entered at the tee, there would be a good chance for the portion between the tee and **h** to choke up as there would then be no water current in that part. It is better to place the lavatory between the tub and closet where possible, because, as shown in the sketch, nothing but the lavatory water passes

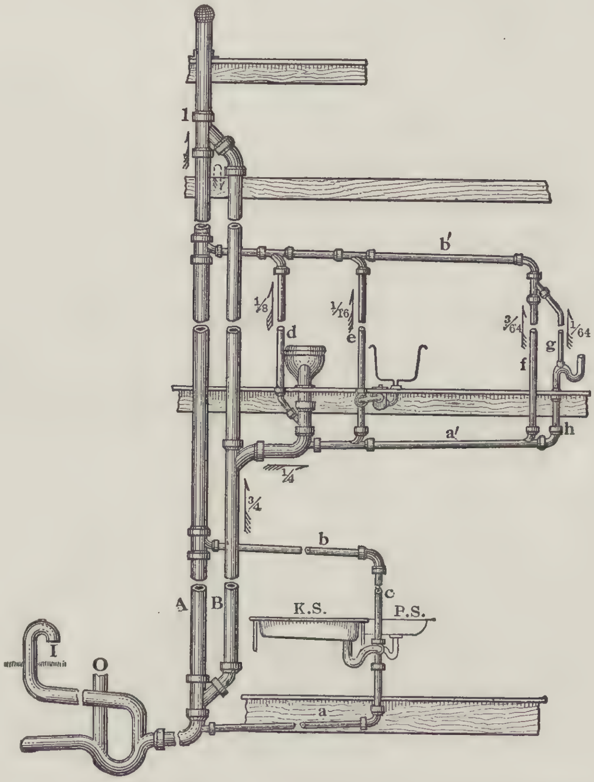


FIG. 325. SOIL SYSTEM ILLUSTRATING THE LOOP STACK, BRANCH LINES, VENTS, ETC.

through **a′**, while if the tub was on the end of the branch waste, **a′** would be thoroughly scoured every time the tub was used and the lavatory would waste directly into a well flushed pipe.

The air travel through crown vents and the evaporation of seal water so brought about is not ordinarily as rapid as generally supposed, but in the arrangement the action of both is the least possible by any likely method. The total vent air carried will prorate with the possible avenues of travel according to heat, use, length, position, etc. Stacks **A** and **B** are the same size. Stack **A** may be said to carry $\frac{4}{7}$ and **B**, $\frac{3}{7}$ of the total, while about $\frac{1}{7}$ would likely pass through the water closet

branch; in other words, with the column passing through **A** given the value of 1.0, as marked in the sketch, the value of **B** volume would be $\frac{3}{4}$, as marked, or 0.75 and that of the water-closet branch $\frac{1}{4}$, as marked, or 0.25,—$\frac{1}{4}$ of **A**, $\frac{1}{3}$ of **B**, or $\frac{1}{7}$ of the extended stacks capacity, as stated. The portion passing through the closet branch would subdivide into the various branch vents according to the influence of the factors named, and would probably have something like the **A** values marked on **d**, **e**, **f** and **g**,—$\frac{1}{8}$, $\frac{1}{16}$, $\frac{3}{64}$ and $\frac{1}{64}$ respectively.

Any form of back vented job is, in a limited sense, a loop-stack if the branch line vents are carried back into the stack above the highest fixture. Whether carried back into the stack or to the roof separately, the branch vents in other methods are longer in the aggregate than necessary with the loop shown, and the disturbance of normal conditions is increased because of their sluggish air travel due to friction of the increased length. With a simple stack, from which the branch line vent air is diverted the column of air passing through the branches is greater. This is generally a detriment, for the house conditions making for an increase in moisture capacity remain unchanged.

CHAPTER LXVIII

Roughing in Fixture Connections

The majority of jobs are small. Such present a greater variety of conditions than the larger jobs and their planning, though generally they have not had the foresight or coöperation of the plumber with the architect or engineer in planning the building so as to minimize structural difficulties in the work of pipe installation. The element of the craft dealing with small work is not always prepared to devise the best ways and means of overcoming either inherent obstacles or those embodied through lack of preconsideration, yet a resulting error, in structure or pipe work, may be as important in one job relative to the structure containing it, as that in another. For these reasons common everyday work was made the basis for most of the sketches herewith.

Fig. 330 is a closet branch, of iron to the hub under floor. There being no lead except the short ferrule **F**, no protection from rats or mice is necessary, but there is in this no provision for shrinkage of building timbers aside from the calked joints,—these will usually give some without leaking or cracking a hub. Whether a tee, or sanitary tee, Y- and $\frac{1}{8}$-bend combined, or separate fittings, as shown, are used is partly subject to ordinance rules in many places. The distance out from wall required for the closet often governs the style of fittings when the stack is nearby. Any lateral branch that can be made with fittings alone is so short that, if all iron, one has to be careful about how the stack is supported,—if it is practically standing on the turn where it passes out through the wall at the bottom, a very stiff lateral will give trouble when side-wood shrinkage takes place.

Taking **F**, Fig. 330, to be at the second floor of a frame house with 2×8 upper joists and the main studs on a sole on top of 2×10 first floor joists, we can count on at least 20 in. of side-wood shrinkage affecting the height from second floor to where the stack passes through the wall. Shrinkage of the best new timber ordinarily obtainable would therefore lower the floor at least $\frac{5}{8}$ to $\frac{3}{4}$ in. and if the stack is direct, stiff, well seated on the hole in the foundation, and the lateral short and stiff, breakage is likely. If the main studs stand on the same plate as the joists sit on, as in strict balloon framing, then only the plate and the side-wood of the second floor joists above the rib-band is to be contended with,—say $\frac{1}{4}$-in. shrinkage. If the house is taken to be brick, the shrinkage of the whole depth of the second floor joists will tend to lower the closet. If the stack is hung to the bottom of the first floor joists, the result is about the same as though it rested on the wall hole.

So called 2×10 joists are generally about $1\frac{3}{4}\times9\frac{5}{8}$ to $9\frac{3}{4}$ in. wide, and unless more seasoned than the new stock of the average lumber yard, shrink $\frac{1}{4}$ in. or more in width after being placed. One can thus gauge the amount of shrinkage to be taken care of on different styles of framing and for different depths of joists and use lead bends to turn up, wrinkled ferrules in the upright, or a Y and $\frac{1}{8}$-bend at stacks where laterals are short and considerable shrinkage is to be provided for, according to conditions. Combined fittings make fewer joints. They may be necessary in close quarters, and can be used direct (without swing) where the shrinkage will be but little.

In new work, the hole where a soil or drain stack passes through the outer wall is often left open above the line with the idea that house settlement will not then be so apt to break the connection outside. This does no good unless the stack is supported by a pier in some wise independent of the house, in which case house settlement would apparently thrust the stack upward, and perhaps break cast laterals. So far as house settlement is concerned it is better to watch the outside connection and let the wall carry the stack down, because everything is lowered alike with it. Where it is presumed side-wood shrinkage will cause trouble, the stack branch may be taken out at right-angles to the lateral run,—thus giving one joint that will rotate in the hub, which, with lead at the fixture end will be flexible enough; or, the stack may be held up by securing to some point above the principal shrinkage element and the *bottom* of the hole where the stack passes out left free of the pipe so the whole effect of wood shrinkage will be merely the lowering of the exit piece in the hole. If the gap between the bottom of pipe and hole diminishes in time, the outside joint must be examined for leakage. Extra fall should be allowed in a lateral that is likely to change pitch from shrinkage.

Short branches are commonly taken out between the floor and ceiling. This saves material. If a lateral is long, the joists narrow, or running contrary, it may be necessary or expedient, to avoid cutting or putting in a header, to show the branch line below the ceiling. If well done, the work thus looks well, even in the minor rooms of a residence, and is far more accessible. The hanging of exposed laterals, suggested in Fig. 330, supposing the floor to be at the dotted level **d** instead of at **D**, is a more important item than many believe. Ordinarily the sole requisite is deemed to be securing the pipe permanently in position, the "how" or "to what" not being further considered. However, if the lateral is secured to the bottom of the joists or to a cross-cleat near the bottom, the whole or nearly all of the side-wood shrinkage of the joist affects the upright connection,—it must shorten under pressure, else the floor end will punch up or the fastening give down. If fastened near the top, the shrinkage element may be neglected, but top fastenings are often

not so readily placed,—a cross-piece on cleats, a bar of sufficient strength crossing two joists for the hanger, or a hook or strap under an upright hub, high up, being necessary. It will be safest in any event, to fasten laterals as high up as convenient. Put a good length of lead ferrule in fixture uprights to provide for shrinkage and bind the lead, however roughly, from hub to floor with galvanized or brass wire mesh to prevent mice and rats from gnawing into the pipe. All this is indicated in Fig. 330,—**f**, being a long ferrule, or ferrule extended, with straight sides as at **a** or, preferably, with wrinkled sides is at **b**; **A**, the joist and **cc′** the wire protection.

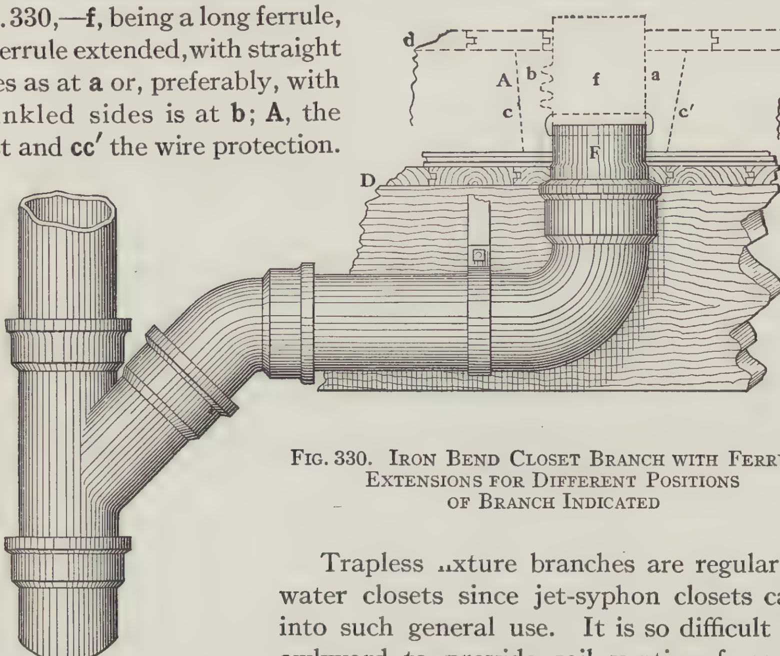


Fig. 330. Iron Bend Closet Branch with Ferrule Extensions for Different Positions of Branch Indicated

Trapless fixture branches are regular for water closets since jet-syphon closets came into such general use. It is so difficult and awkward to provide soil venting from the pedestal of jet-syphon closets at any permissible point that such is not attempted. It is quite usual to provide a change of air in the upright of closet branches by a 2-in. iron branch pipe (not shown in Fig. 330) to the vent from a hub in the upright, or by wiping 2-in. or less lead pipe into the lead extension.

Fig. 331 shows the stack branches for an ordinary bath room. **T**, is an underfloor trap wiped to a short ferrule. This branch is suitable for any form of closet, hopper closet, slop fixture or drain requiring a trap under floor. No crown or lateral vent is shown. Such is often omitted and is not an essential vent for short connections; though not necessary to provide against syphonage in many forms of fixtures, it is, to prevent syphonage in some forms, absolutely necessary on account of the volume of water discharged at once by the fixture. A bend, $\mathbf{T}^1$, shown dotted in, is suitable for any fixture trapped above the floor when the outlet is well out from the wall. The bend to meet the straight ferrule can be worked by hand, or a bent ferrule may be used. A $\frac{1}{8}$-bend, factory

made, or worked on the end of straight pipe, on the job, can be set, as **T**^{2}, for fixture outlets near the stack. A bent ferrule with straight pipe answers to get the desired position, but a bend in the lead is better, for a bend of any degree in lead favors the shortening of distance necessary to meet timber shrinkage. **S**, is the soil and waste stack,—**SV** its vent. When there are no fixtures discharging into the stack higher up, crown or lateral vents may enter anywhere above the closet branch fitting. The lavatory and bath waste, etc., enter the stack through a side opening as shown. This branch may be all lead, as indicated at **K**,—well supported, well protected from frost by boxing and packing, if necessary, and in some way isolated from rats and mice. When a bath branch is long, cast iron pipe and fittings, suggested by **K**^{1}, are often used to the exclusion of lead except for ferrules, traps and connecting pieces. If frost protection is unnecessary, the iron pipe, cheaper in itself is further cheapened by the difference in cost of support and rat protection.

Where mineral wool is used to protect pipes and traps from frost it also acts as a fair protection against rats and it has the further merit of offering no chance for spontaneous combustion. Chance fires are possible in two ways in felt scraps, old rags and other combustibles, sometimes used for box packing. A little oil in cloth material or a live match in a mouse nest are both likely and not seldom actual sources of apparently mysterious fires.

Of Fig. 332, T^3, T^4, T^5, **SV** and **S** have the same functions as mentioned for corresponding pipes in Fig. 331. T^3 being a P-trap, the vertical height necessary to entirely hide the branch is less than for the $\frac{3}{4}$-**S** shown in Fig. 331. In this sketch, the bent ferrule is indicated in two positions, though it is not so desirable when looking vertically, because of the stiffness, unless the vertical piece is rather long, as when the branch is taken out below the ceiling. Where the joist depth is extra shallow, a sanitary tee, with straight ferrule may be used in place of the **Y** and bent ferrule, if it is desired to entirely conceal all evidence of the branch from the view below. Wiping in a vent so directly over the seal water as is almost necessary and quite the likely way for a P-trap, and as shown at **TV** does not affect the life of the seal water so much in such cases as one might believe prior to mature reflection,—the trap is large, volume of seal water considerable, percentage of trap heating surface the least possible, the vent relatively small and the soil stack air current prorated with the stack continuation, with all branch-line vents and with all crown vents connecting with the stack. When a bent ferrule is used as at T^5 the branch for other fixtures (**K**^{2}) must be taken from a stack fitting. When the main branch terminates in a trap, the branch, if it is to be all lead, is generally entered at **K**^{2}, and is thus independent of the big trap seal. Some mechanics prefer to enter fixture branches on the house side of the big trap seal, taking the view

that it is a double protection. Some material is thus saved, but the air in the small waste is stagnated, and if the big trap becomes choked the other fixtures are thereby out of commission for the time being. Wherever entered, the branch must be above the seal water level to prevent air that would otherwise be trapped between two seals from interfering with the free passage of waste from the fixtures attached to the branch pipe. When the principal branch ends with a lead bend, **K**^{2} may be entered into it at any convenient point.

Iron soil pipe traps are used in some localities in place of lead wherever convenient.—if shrinkage can be otherwise provided for. In frame

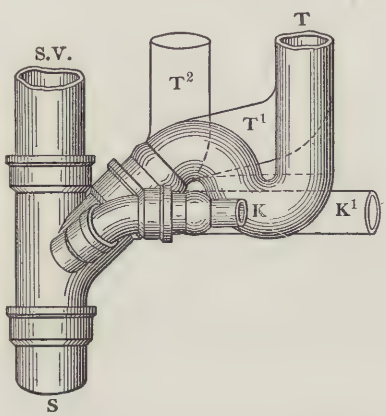


Fig. 331. Lead Trap Closet and Hopper Branches, with Side Opening in Soil Pipe Stack for Branch Waste for Bath, etc., Indicated

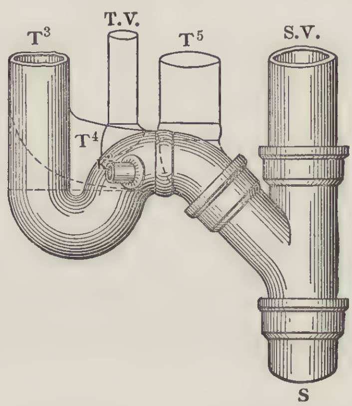


Fig. 332. Lead Trap Closet and Hopper Branches with Branch for Bath, etc., Entered Into Lead Trap on Sewer Side of Seal

buildings, the stack is, for this purpose, sometimes hooked to the main studding and a 4×6-in. or longer lead ferrule used above the trap. This gives an inch or two of lead pipe below the floor line in which, by the aid of the bossing stick or ball pein hammer, is dummied a wrinkle that adds greatly to the flexibility of the short lead portion.

In Fig. 333 are shown two branch pipes entering the closet trap, one at **E**, below the seal level, the other at **e** above the seal on the house side. Formerly, both of these practices were usual, both being sometimes employed in the same trap. The idea was to make the closet trap answer for all the fixtures in its neighborhood,—a poor method, but yet indulged in on much common work outside the jurisdiction of sanitary laws, though open to several valid objections. The bath tub waste, not so frequently used, but scouring in action, was usually entered at **E**,—a tolerable arrangement when the connection is short and without a separate trap. Any fixture waste entered at **e** has trap protection from the soil pipe, but, where a trap is under floor there is every likelihood of there being a hopper or some other fixture above offering an

open channel from the trap to the room and an untrapped fixture connecting at **e** therefore provides a passage for air in the room to circulate through in one direction or the other, which it does, filling the room with foul odors. If a fixture on **e** is trapped and the branch vented, closet bowl odors are reduced by a faint current down the main connection if open and up the vent. All fixtures connected to the main trap help, of course, to insure maintenance of its seal.

It is safe to say, of any questionable practice, that a workman capable of getting the best result from a poor method and having the liberty to go to the expense of doing so would simply substitute the better method at the outset.

It may here be said that the traps in a common single bath room residence jobs tend to lose their seal by evaporation faster than those in some other positions. The lines are not long as in store building work. There is therefore less moisture taken up from wet interiors, so vent air comes to the traps less humid. In jobs with fixtures connected to the same stack on different floors, the upper laterals receive currents from the stack more nearly approaching a saturated condition and thus have a diminished capacity for moisture, to be satisfied at the expense of seal water.

A tapering ferrule or funnel, flanged at the top and set in the mouth of the closet trap so as to dip an inch or so in the seal water is shown in Fig. 333. This was the plan generally resorted to for adapting a trap under floor, having branches like **e**, to a new form of closet requiring isolation from branch pipes. Nearly all of the pneumatic syphonage type of closets once in general use in the better run of work depended for syphonage upon the rarification of the air in a space between the seals of two traps. This was generally accomplished by the air in the space being stretched out to fill a void left by the falling water in a special compartment of the tank. Closets having both traps in the earthenware proper were good for new work where the roughing in could be done to suit, but for renewing, a trap under floor usually had to be removed and the branch pipes changed or reconnected to a bend. This led to the marketing of the one-trap type in order to use old roughing in, much of which, however, had to be adapted in the way shown. Even though the branch pipes above the seal were trapped at the fixtures, they were still a detriment to proper syphonage because the air in them had also to be rarified and the air space of the single trap type of closet was already large. The inner pipe shown, set in by the plumber, isolated branch openings above the seal, reduced the lead trap air space in connection with the closet and left an annular space, as shown, for the waste from branch pipes to flow down through. As shown, the dip pipe was in some cases tapering and set concentric as at **X′**, and in others, simply of smaller pipe dummied out at the upper end, as at **X**. Many

of the traps in old work are $4\frac{1}{4}$ and $4\frac{1}{2}$ in. in diameter. These left ample room for branch waste between the walls, but the later work, being smaller, the mouth of the old trap had to be enlarged for some closet nipples and it was frequently necessary to set the dip pipe at an angle so as to leave sufficient space on the side where the branch waste entered. The dip pipe flange was usually soldered to the trap flange. Crown vents were rare in old work and generally had to be added for

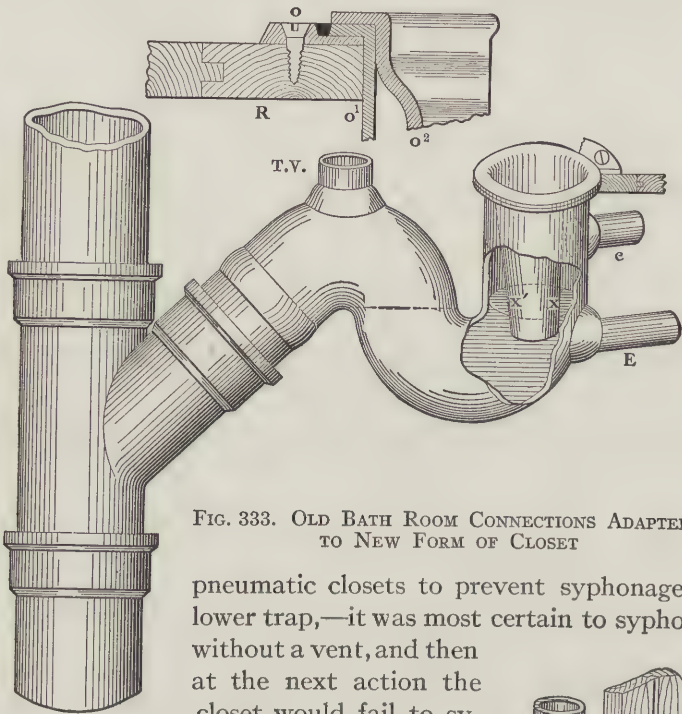


FIG. 333. OLD BATH ROOM CONNECTIONS ADAPTED TO NEW FORM OF CLOSET

pneumatic closets to prevent syphonage of the lower trap,—it was most certain to syphon when without a vent, and then at the next action the closet would fail to syphon. The detail sketch **R** shows a floor screw through brass floor flange at **O**, trap wall at **O¹** and dip pipe wall at **O²**.

Sinks and lavatories are frequently roughed in for wall connection, so as to free the floor of pipe obstruction, either by branches from main stacks or their under floor laterals or by independent stacks. For sinks there is ordinarily no better way than to turn the hub of a sanitary tee out through the wall as at **N**, Fig. 334. A Y-fitting not only makes an ugly hole but is more difficult to fit the trap to in a way to look well,—that is, in order to have the trap outleg in proper alignment with the Y-branch when

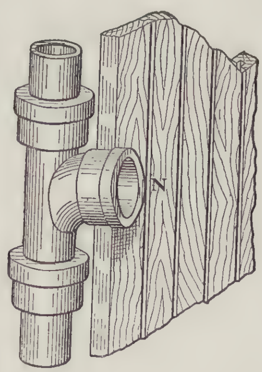


FIG. 334. SINK OR LAVATORY CONNECTION WITH HUB OF CAST PIPE PROTRUDING THROUGH WAINSCOTING—WASTE STACK CONCEALED IN PARTITION WALL

finished, the height and position of the sink outlet when set must be closely reckoned with as well as the spread of the trap in finding the height for the Y in the line. The ferrule can be wiped on to the trap on the floor. When running the lead joint in the hub, the wall should be protected by a piece of pasteboard with a hole in it fitted snugly over the hub.

Kitchen sink wastes passing through the floor should be fitted with iron pipe terminating in a hub standing above and resting on the floor, as shown in Fig. 335. When lead pipe sink wastes continue to and through the floor, mop heads and scrub brushes soon disfigure them to the extent of needing repairs, to say nothing of the sorry appearance of the pipe when compared with its surroundings of the same age,—an iron hub cannot so be made to leak nor thus jolted out of shape. It is frequently better in residence work to omit the sink waste when roughing in and extend it from the stack in basement to just where the sink and trap used require it, when finishing.

If the wall is thick enough, lavatory branches may be set in Fig. 334 position, but a lead ferrule should be included in the roughing in work and the face of the hub situated back of the finished wall line. Partition walls are seldom thick enough to do this, and where the branch is from a continuing line, the tee or Y is turned to the side and the branch brought to the wall surface by means of a ferrule wiped to a lead bend and set in as shown in Fig. 336. If the water test is to be applied to the roughing in, the end of the bend can be left protruding as far as it will, the end being pinched flat and soldered. If wood wainscoting is to be used, the bend may come in the middle of a piece; then it is best to solder a lead disc into the end for the test, thus leaving the end of the bend circular so the carpenter can bore a hole for it and thus leave a good wall surface to flange on.

No attempt to stretch an end large enough for a flange joint should be made, when finishing,—the edge would be thin, out of true, probably split, and afford a poor stop-edge for the flange joint. The proper way for all flange joints is to cut a lead washer of the diameter desired for the joint and flange the pipe over it, as at **Y**, Fig. 336. Cardboard protection for the wall and floor should be slipped over the pipe as shown in Fig. 336 before flanging,—it can be cut away after the joint is made.

In Fig. 337 are illustrated by sectional sketches the principal modes of connecting lead pipe to cast and wrought pipe. The regular combination lead and iron ferrule is shown by **A**, **a** being a cast thimble of the same internal diameter as the lead part, $\mathbf{a}^1$, above the ferrule. The shoulder where the lead offsets over the ferrule end not only preserves an equal bore but leaves more room outside to yarn up and calk the lead joint where short ferrules are wiped on. The lead stock is thicker at the shoulder than elsewhere. The iron thimble keeps the lead from crush-

ing in when calking. A ferrule similar in appearance is shown by **B**, **b**[1] being the lead and **b**, a metal thimble or ferrule covering the outside of the lead, as shown, and tinned on to the lead in the making. **A** and **B** are sold by supply houses and have paper pasted at the joint part so the lead of the ferrule will not melt when pouring molten lead into the hub. Sketch **C** shows a job-made ferrule. It consists of a thimble of

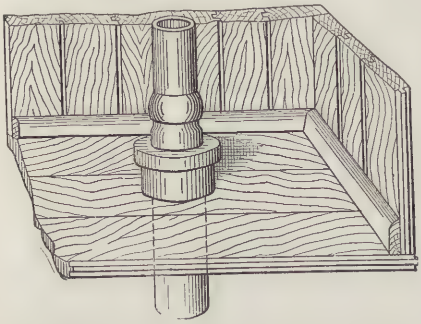


Fig. 335. Sink Waste Branch with Hub Projecting above Floor to Protect Connection from Mop Heads when Scrubbing

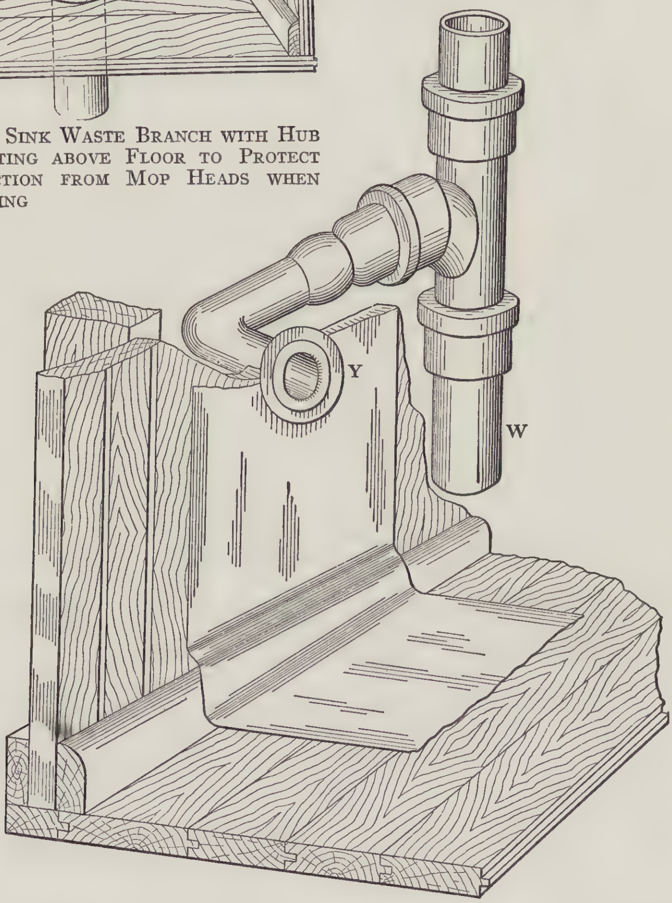


Fig. 336. Sink or Lavatory Branch—Lead Connection with Line in Wall

cast soil pipe inserted as shown. If the pipe is 2-in., the end is swelled with drift plugs until the thimble will enter far enough. The lead is then turned over the thimble end, the ferrule portion of the pipe paddled down into close contact with the thimble and the pipe "shouldered" in to give interior alignment as shown,—the latter being done with the

bossing stick and face corner of the dresser; if the pipe is 3 or 4-in., it is dummied out with the bossing stick, back of the dresser or whatever will work in the pipe most effectively;—hold the pipe in one hand and the tool in the other and strike by moving *both hands*; this greatly increases the velocity of the blow and is equivalent to a stroke made in a pipe of twice the diameter. The thimbles can be cut from scrap pipe

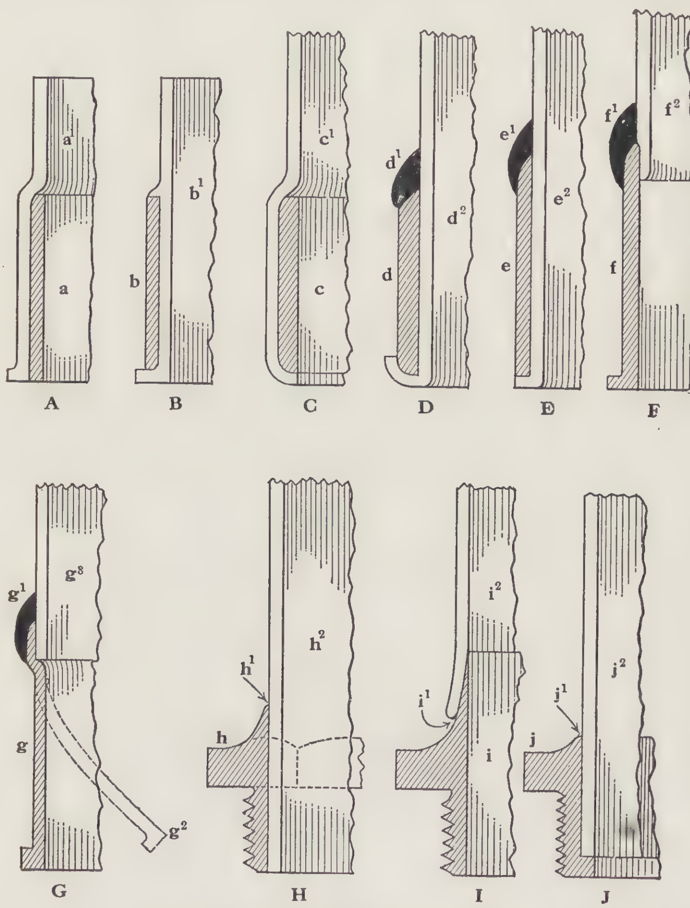


FIG. 337. VARIOUS METHODS OF JOINING FIXTURE WASTE PIPES TO MAIN LINES OF WROUGHT AND CAST IRON PIPE

and should be 3 in. long. Smoother thimbles that require less swelling of the lead and therefore give more lead joint space can be purchased. **D** shows the way in which many pipes less than 2-in. are connected by slipping the lead through a brass or iron ferrule and wiping to it as at **d¹**,—**d²**, being the lead and **d** the ferrule. When the ferrule is of brass and long enough this makes a good job, but, I am sorry to say many iron thimbles are so used, and not all of them are wiped on. The necessity

for soldering is to keep the lead pipe from sagging over the thimble end,—a tight calked joint, that will not leak in the lead space nor between the lead pipe and thimble can be made by turning the lead up extra high outside, yarning a little between the *lead* and hub surface and then pouring a very hot ring of lead into contact with the lead of the pipe end.

Whether 1½-in. or 2-in. pipe is used for the thimble depends some upon the size of lead pipe used,—ordinarily the lead must be swelled to fill the thimble. 1½-in. pipe makes a very thick calked joint. Section **E** is of a brass pipe thimble slipped over the lead pipe and wiped to it; **e**, is the brass, $\mathbf{e}^1$, the wipe joint and $\mathbf{e}^2$ the lead pipe. Section **F** is a common cast brass ferrule wiped to lead; **f**, is the ferrule, $\mathbf{f}^1$ the joint, and $\mathbf{f}^2$ the pipe. Section **G** is a brass hub-ferrule; **g**, is the brass, $\mathbf{g}^1$, the joint and $\mathbf{g}^3$ the pipe; $\mathbf{g}^2$ indicates a bent ferrule. A fault with **F** and **G** ferrules, not reducing, is that, as furnished, they are entirely too short,—**G** especially, for the hub further aggravates the work of calking in. If the makers had to calk in a few such ferrules after they were wiped on, the length would soon be increased and the sales improved. **H**, **I** and **J** are threaded ferrules or connecting pieces, being brass stubs with wrench shoulders sweated to lead extension pieces. The brass part is made short to reduce the necessary wall depth and thus permit flanging the lead at the wall when the brass is screwed into a wrought vent or drainage fitting standing in ordinary partition walls. **h**, **i**, and **j** represent brass; $\mathbf{h}^1$, etc., solder, and $\mathbf{h}^2$, etc., lead. Where the length makes no difference a common brass solder nipple can be used,—slipping the lead through it, sweating to the brass at the thread end and wiping the tail end to the lead at the other, as usual.

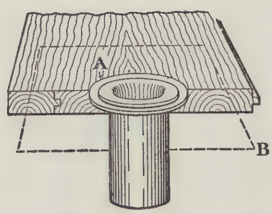


Fig. 338. Floor Waste with Cardboard Under Flange to Protect Floor while Wiping the Joint

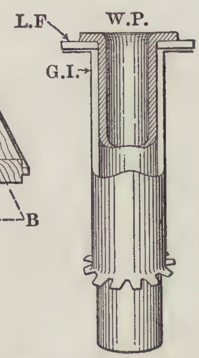


Fig. 339. Floor Waste with Sheet Iron Ferrule to Protect Lead Pipe from Rats

Fig. 338 illustrates a lead pipe flanged over a lead washer at the floor line, as might be done for a lavatory or bath waste, or vent pipe,—**A**, being the flange washer and **B** representing cardboard to protect the floor surface while wiping. If a pipe is flanged before the cardboard is placed, two pieces can be circled out for the pipe and slipped under the flange far enough to lap the ends.

Where a lead pipe passes through wood in any position that invites

rats or mice to attack it, a good plan is to cover the lead with a sheet metal sleeve much as steam fitters do for protection of the wood from heat. This is illustrated by Fig. 339; **WP** is the waste pipe; **LF** the lead flange, and **GI** a galvanized sleeve. A flange can be soldered to the end or it can be peened out sufficient for the floor or wall surface end. If the pipe also passes through a ceiling below, make the sleeve long enough to also pass through it and flange the sleeve out as shown at the lower end in the sketch, the sleeve first being slit for the purpose with the snips. The prong flange can be concealed with a plate, or by cutting it a little short and flanging at the face of the laths and then pointing up over the prongs with plaster of Paris.

Urinal roughing in for ordinary work is much like that done for other fixtures, consisting of providing a waste opening or waste and vent at the points required for the fixture to be used. If a number are to be installed in a battery, perhaps one waste and vent opening will suffice in the rough, and manifold lines behind marble backs, installed when finishing, will take care of the individual fixtures. An instance of roughing in is given in Fig. 340. In this, the trap, supply, flush pipe, etc., would be accessible only from the back, as most stall work is, with the exception of the traps which are more often placed directly beneath the urinal outlet when local ventilation is not a feature. It is only in the most ordinary installations or in adverse situations that the waste, trap and supply is placed wholly exposed to view on the face of the wall. Individual hand flushing cocks are rare in city work aside from odd single urinals in common jobs. Flushing rim urinals that cleanse all of the inner surface are now all but universally used, iron urinals, and closet bowls too, being now made with integral flushing rim like earthenware goods.

Automatic time flushing tanks are as a rule the means of cleansing urinals. Local ventilation is provided in good work where circumstances will permit. Specifically of Fig. 340, **WS** is the waste stack; **BW** the branch waste line; **VS**, vent stack; **LV**, local vent branch; **BrLV**, branch local vent for battery of urinals, and **LVS** main local vent stack. In small jobs where power is lacking to obtain positive local ventilation offers some difficulty at times. There is not always an available flue continually hot, the heat of which may be taken advantage of by building the duct or main flue adjacent to or in it; heating plants do not furnish a means of warming accelerating coils in vent ducts throughout the year; gas burners used for creating draft are a continual source of expense; induced draft ventilators are effective only when the wind blows. All of these schemes are used more or less, according to circumstances. In summer there is usually little need for accelerating equipment of any kind, but in other seasons, especially in the dead of winter, reverse currents may flow in by every favorable

opening, from wind, or to supply the call for warm air leaving the house at some exit so situated as to offer less resistance. In some buildings the heating and ventilation is accomplished by driving in warm air without specific exits. When the building is thus in the plenum no natural inward leakage takes place, as is the case when direct radiation is depended upon without exit registers, but instead the change of air takes place by outward leakage, and of course local vent openings in such buildings take care of some of the outgo with admirable effect. If cool air is blown in during the summer they are then also equally active,—in the dual service of ventilating the house and removing odor from specific parts of it.

Local vent mains are made of galvanized iron; are nearly always rectangular and are reduced in area in the same way as other pipe mains, as the branches are taken off. The branches are made round or rectangular according as the space, size of branch or dimensions of the main suggest. Connecting nipples and sleeves are made round. The ultimate connection with the plumbing pipe is soldered, or puttied and taped over a slip connection, or, however else specifications may direct. There is no call for a strong joint, but leakage at connecting joints lowers the efficiency of the vent more or less.

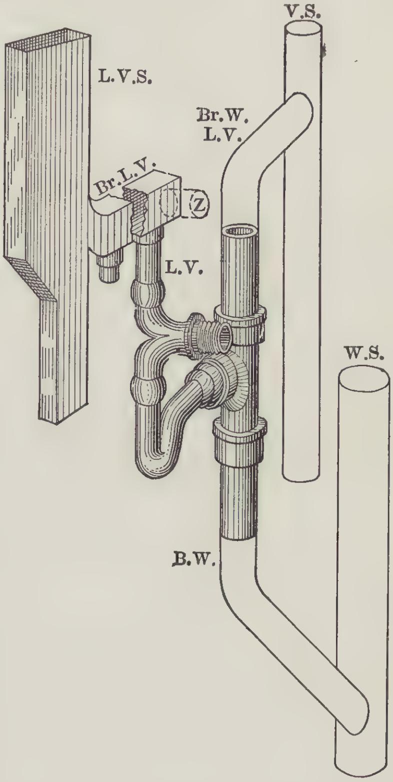


Fig. 340. Urinal "Roughing In," Local and Waste Ventilation Shown and Vent and Waste Stacks Indicated

Ducts of the same character as shown are used in water-closet local vent work,—being placed lower down of course, and the connections taken from the face of the branch duct as indicated at **Z** in the sketch.

In Fig. 340, the double-ell connection has a long thread on the fixture end; this, with a lock-nut, affords means of adjustment to different thicknesses of back wall. The urinal outlet piece couples to it at the face of the back slab. Waste and vent air pass out through the same opening in the urinal.

If the branch waste and vent pipes shown are serving a number of urinals, they would be extended from the mains with proper fall and

each urinal waste would either drop into the waste line or go into a short vertical pipe connecting to waste at bottom and to vent at top, the trap connection and vertical tee being just as shown, for each. When the waste connection to a vented portion is so very short as the plan just named and as the work in the sketch shows, it is not usual to add a crown vent to the trap,—the amount of water discharged is not enough to syphon the trap; no vacuum sufficient to do so can be produced, and the "dead end" is too short to require special ventilation.

In batteries where the separate wastes drop into a manifold branch waste, crown vents are sometimes connected to a manifold branch vent line, the branch vent and waste being connected at the extremities by a water washed vertical connection like shown in the sketch.

For common bath tub connections where the trimmings supplied with the tub consist merely of a waste plug with coupling and horn overflow, the plumber must provide considerable more work, either above or below the floor, than where the factory made patent overflow and connected waste is used. The usual plan, and a very good one, is shown in Fig. 341. The crown vent **V**, is not always provided but should be, for, while baths are not as frequently used as other fixtures, the volume of water passing at once is large enough to syphon the trap if possible under the conditions of the work. If the bath connection is $1\frac{1}{4}$ or $1\frac{1}{2}$ in. (it is but rarely larger) and a 2-in. trap is used, there is little likelihood of the trap syphoning while it is clean, and no fixture trap stands a better chance of remaining clear than one of the kind shown, under a bath tub. Traps with large bodies stagnate the flow some but the seal is more likely to resist syphonage and to survive a period of non-use, and at the same time the currents in the trap are not so likely to bunch foreign matter into a capillary mass. The shape (S or P) of trap used ordinarily depends upon the position of the pipe to be reached.

The author has often employed in S-trap position an extended outlet P-trap standing in normal position but reversed and with the outlet end formed into a bend looking upward to receive the tub waste. The overflow pipe is branched in between the two trap ends on the house side of the seal and the actual waste branched out of the side of what would have been the inlet leg if used as a P-trap.

This requires no more joints or work than the arrangement shown in Fig. 341 and has the advantage of enabling the plumber to wipe in the waste at any angle convenience may suggest and high enough to give any depth of seal desired. The inlet of the "P-trap" becomes the vent, or in the absence of the vent may be fitted for a clean-out. **C**^{2} is wire mesh protecting the lead from mice; if without this or other adequate protection, ferrules of sheet metal, as at **b**, should be dropped over the pipe ends before flanging them down. **W** and **O**, in the sketch, stand

for waste and overflows. Little choice is usually made as to which end is used for waste, though the branch is the proper end, for if it is used for the overflow there is some chance of matter lodging and drying, in time, in such a bend and when an overflow does occur it may for this reason, not carry the water off fast enough.

Bath tubs are generally too low (near the floor) and the waste couplings too long to make a neat combined overflow and connected waste on the job. Few occasions to do so come in regular work, but now and then the lack of regular fittings necessitate such work in localities remote from supplies in cases where the roughing in has been placed for factory fittings. The best way is to close the end of a pipe, cut the waste

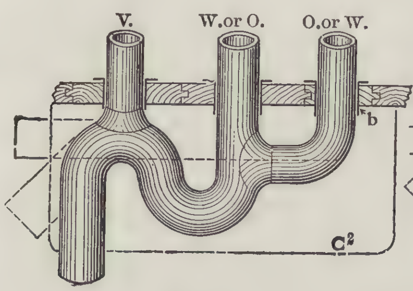


Fig. 341. Common Lead Bath Trap with Vent and Overflow Wiped In

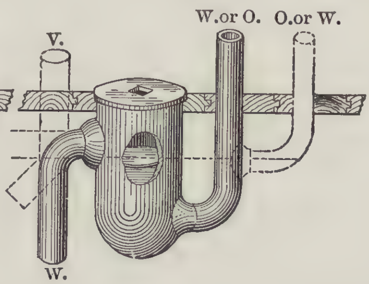


Fig. 342. Bath Drum Trap with Extension Clean-Out Cover; Connections Wiped in—Style, Sewer Air Against Cover Gasket

coupling as short as it can be used and wipe it into the side near the closed end; a bend can then be made to meet the waste opening and the overflow dropped into it, or the waste may be branched into the overflow and the end of the overflow, wiped to the floor opening, which ever accords best with the position of the floor pipe.

Fig. 342 is a drum trap with the overflow or waste branched in low down and the waste taken out high. There is no objection to this so long as the gasket of the cover is kept tight. This is quite improbable, however, as the cover is known to be a cleanout and some one in the household, perhaps a boy, out of curiosity, is sure to unscrew it sooner or later, even though not before stoppage or sluggish flow ensues. Such large delicate gaskets often get brittle enough to break when disturbed and any one but a plumber is not likely to pay much attention to the gasket. It is not necessary to branch one pipe in to the other as shown in Fig. 342. Both may be entered directly into the body of the drum, low down for style Fig. 342, or, high up, as shown, for style Fig. 343 in which the pipes are entered so the sewer air will be against the water seal instead of the cover gasket. A P-trap, inverted, can be used (for S-position) for the drum outlet, if desired.

For wastes in P-position it will be found a little quicker and just as

cheap to cut a running trap in the center and use each half for a trap outlet like shown in Fig. 343.

A projecting cover should always be used with drum traps, as the floor fitting is never perfect and chance weight would otherwise injure

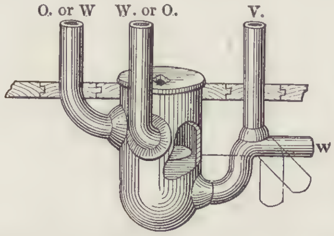


Fig. 343. Bath Drum Trap with Extension Clean-out Cover—Waste Inlet, Outset and Overflow Wiped in—Style,—with Sewer Air Against the Water-Seal

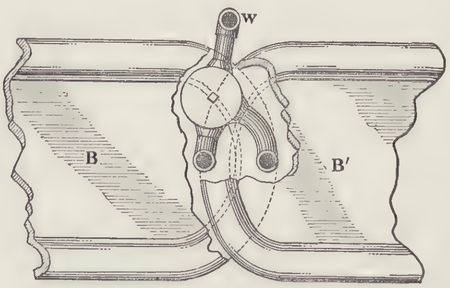


Fig. 344. Plan of Drum Trap Setting—Cover Accessible without Being Too Prominent

the trap or connections. When a trap is under a bath tub, the cover should have a projecting wrench square, because the countersunk type is difficult to turn when not in open space.

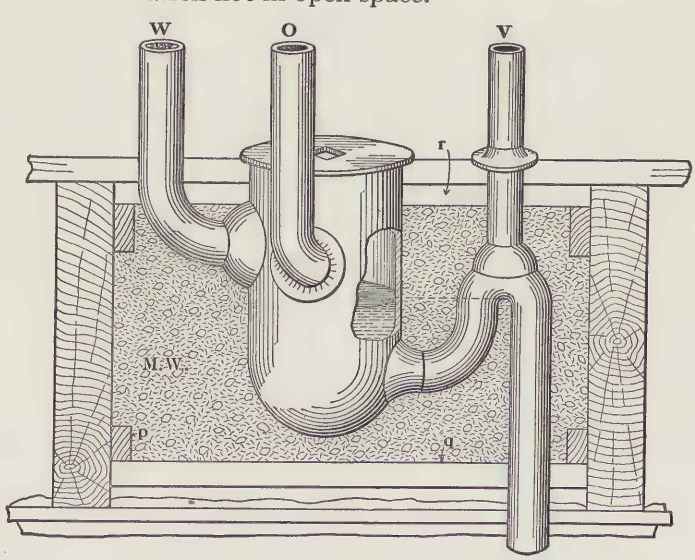


Fig. 345. Methods of Protecting Traps between Joists, from Cold Air Currents to Prevent Freezing

In Fig. 344 is a plan view of a drum trap with all branches made in the body like in Fig. 343, but at the levels shown in Fig. 342. The position shown, back of the waste but not actually under the tub, is not conspicuous, is fairly accessible, and all things considered as good or better than any other when there is room at the end of the tub. The

two openings are for waste and horn overflow. For the general run of work only one intake is necessary,—placed at overflow or standing waste position—the one next **B** for **B′** tub position, and vice versa. There is, of course, no certain position for these traps,—they are placed anywhere reachable, near the intake, to suit the pipe.

Fig. 345 shows a trap boxed in and packed around with mineral wool. This work when necessary at all should be done when the roughing in is placed. The pipe and trap are thus protected from chance injury during the interval and the frost packing is not forgotten later because the place needing it is out of sight, and there is, when it is attended to in the rough, no floor to take up and plastering to be jarred off in fixing the box. **q** is the bottom board of the box; cleats **P**, should be nailed to it and then put in place and nailed to the joists; two other cleats of the same lengths are nailed to the joists directly above; the end boards can then be nailed on; if short vertical cleats are first fitted between the others at each end on each side the box will be less likely to leak the filling. When the box is packed, with all pipes in proper position, a top board should be bored and let down over them, tacked in position and the trap cover screwed in loosely with paper over it. The whole should then be roughly boxed over to protect the work until the carpenters are ready to lay the finished floor which brings the surface up to where the cover extension will rest on it.

CHAPTER LXIX

Types of Pipe Traps

Fig. 350 represents an "S" trap; Fig. 351, a $\frac{3}{4}$ "S"; Fig. 352, a $\frac{1}{2}$ "S" or "P" shape; Fig. 353, a Bag "S" trap, and Fig. 354, a running trap. For fixture use above floor the "S" trap is used where the waste of the fixture connects to a pipe at the floor; the $\frac{3}{4}$ "S" generally enters a Y-branch in an exposed vertical line; the "P" is used with vertical tees, sanitary tees, and combined Y and $\frac{1}{8}$ bend fittings; the bag in one shape or another is "roughed in" for where the fixture outlet must come directly over the waste and in cases where the fixture outlet is too close to the wall to permit other forms of trap to be used, to the wall. The "running" trap generally serves for a set of trays. For under-floor use, the shape of trap that will bring the inlet to the desired point with the least material or work (cost) should be used unless it will occasion some awkward course likely to choke easily. The bag trap is made in standard shapes, and the various forms in which it may be used are indicated by dotted lines **A**, **B** and **C**, Fig. 353. The Running trap is made in the "Running-Y" form, dotted in at **D**, and in the "Running 'S' " shape indicated by **E**, Fig. 354. Most of the traps shown are made in "S," $\frac{3}{4}$ "S" and $\frac{1}{2}$ "S" or "P" form, and all of them are adaptable to the requirements of any position. The interior of all traps should be accessible by trap screw, hand-hole or otherwise, and the location should be such that the trap can easily be reached at any time. Any of the traps Figs. 350 to 354 inclusive, can be cut at **a** and rejoined with the outlet pointing to any direction in the horizon not occupied by the drop-leg,—an advantage to shops remote from supply sources.

Fig. 355 is what is known as a Flask trap. There are many makes of the same general pattern, vented and unvented, all with the outlet and inlet in the same line. The flask pattern is usually of cast brass, is of good appearance and quite reliable, though of rough interior; one integral partition projects upward to retain the water and another downward, to below the water level, seals the sewer air from the house. These traps have the minimum of surface and the course of the water through them is about the same as through a common "S" trap. The bad features are the chance to lose the seal through the weir, or bypass the air through the dip. The small amount of water held and high conductivity of the metal both tend to loss of seal by vaporization in a comparatively short time.

The Drum or Pot trap shown in Fig. 356 is, as a stock article, merely 8 or 10 in. of 4-in. lead pipe with one end closed and the other furnished

with a trap screw. The cover of the screw is made with or without projecting flange, and with raised or countersunk wrench hold, according to whether the cover is to be fitted to a floor surface or not. The trap's chief merits are: it holds a great volume of water, and will not soon evaporate dry; is accessible and easily cleaned; can be used in lieu of any standard form and the plumber can enter the inlet and

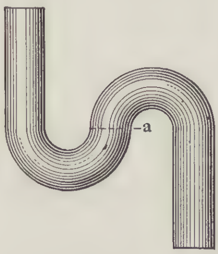


FIG. 350. "S" TRAP.

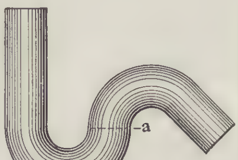


FIG. 351. "¾-S" TRAP

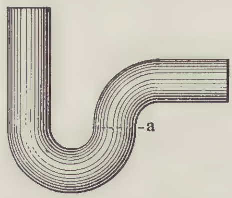


FIG. 352. "P" TRAP

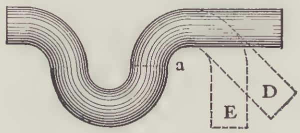


FIG. 354. RUNNING TRAP

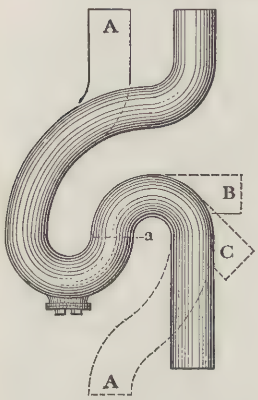


FIG. 353. BAG "S" TRAP

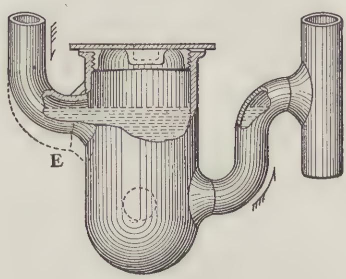


FIG. 356. DRUM OR POT TRAP

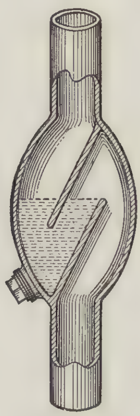


FIG. 355. FLASK TRAP

outlet at any angle to each other required. The branches are almost invariably opened and the pipes wiped in on the job. In the sketch, the outlet is water sealed,—this keeps the sewer air from coming in contact with the cover gasket, which after long service, may not be air-tight. If the level of the inlet and outlet are made just the reverse of that shown the trap is not easily syphoned but is suspectible of sewer air leakage at the cleanout.

With the outlet at **E**, leaving more of the body above it Fig. 356 would appear about like a well known non-syphon trap. By adding a hood retainer inside the body, that will fill with water and not empty quickly, Fig. 356, as shown, cannot be syphoned. Traps with pot body, for use above or below floor, with retaining pockets that catch and hold enough water to maintain the seal are made. If the inlet of drum traps is entered too low, say at the level of **E** in the sketch, the inlet pipe is

sealed (unavoidable if connected reversed from the manner shown) from the air cavity under the cover and water leaving the fixture does not flow perfectly free until the inlet pipe is well filled with water. Wherever lead traps are used under floor, they should be protected from rats, however clumsily the work may be done, by bending and fitting some sort of sheet iron, copper or zinc, or wire mesh about the trap, especially where the parts pass through walls or floors. The better way of connecting is shown by Fig. 356, and the trap should thus always be vented.

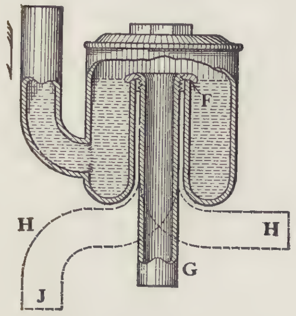


Fig. 357. Open Wall Non-Syphon Trap

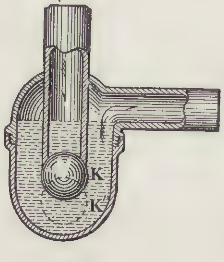


Fig. 358. Mechanical Seal Operated by Flotation

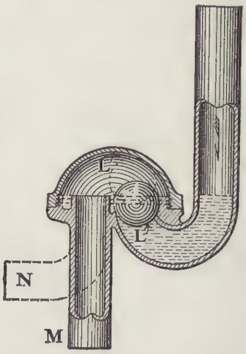


Fig. 359. Mechanical Seal Operated by Gravity

An improved open wall trap is illustrated by Fig. 357. In it all water walls are exposed and there is no chance of unknown water leakage, nor means of by-passing the sewer air into the house; no form of line vent connection in this has much influence toward absorbing the seal water, as the vent air is not carried close to the seal water nor directly to its height. With the inner projection on the outlet, **F**, more pronounced and at the right angle, it can be made to deflect or hold water to prevent breaking the seal by syphonage. By entering the inlet tangentially the surface is scoured by the mass of water rotating in the body and the trap becomes one of the centrifugal self-scouring class. **G** is the "S" form outlet; bag "P" and "S" outlets are indicated by **J** and **H**.

A trap with a light rubber ball in the body at **K**, is shown in Fig. 358. The ball seals the inlet by flotation when the trap contains water. Water entering from the fixture drives the ball away from the inlet as indicated at **K′**. The proportion of the body and dip must be such that the ball will float to the proper position. This trap is not easily syphoned but should be vented. The dip pipe is open to the usual objections. Another form of mechanical seal trap is roughly shown in Fig. 359. It cannot be unsealed by syphonage. The ball seals by gravity instead of flotation and the passageway of the trap is closed even though no water is contained. Metal balls and rubber-surfaced

balls are used for this type of seal. The crown of the trap must be so shaped that the ball cannot get over the outlet, so it will not get wedged in any position when off its seat and so it will gravitate to the seat; **L** represents the ball when seated and **L′** when unseated; **M** is the "S" outlet and **N** the outlet for "P" form.

A form of non-syphon trap much used is represented by Fig. 360, a side view outline being in solid line. The dotted front view shows the side extension of deflector case **X** (dotted in side view), by dotted line **X′**.

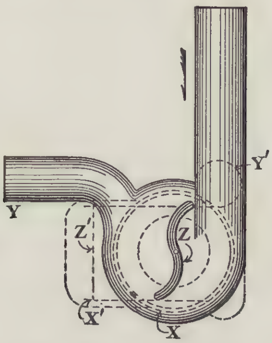


Fig. 360. Non-Syphon Trap with Deflector and Chamber

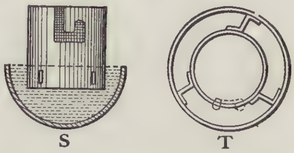


Fig. 361. Refrigerator Trap

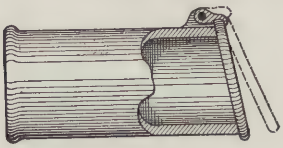


Fig. 362. Gravity-Hinged Cover Used on Safe and Tank Overflow Pipes

The outlet **Y′** is also dotted in. The deflector **Z**, seen endwise in solid line extends outward into the case as shown by **Z′** dotted line. The "P" outlet in side view is shown by **Y**. The deflector case is detachable. The deflector (removeable) helps to retain enough water to insure maintenance of the seal, and the water passing out around the deflector produces a scouring effect. Those interested in this trap devote several thousand words to making more or less clear its entire construction and action. Indeed, trap literature elaborate enough to do justice to the inventors would make a volume, and the reader should not dismiss the subject without reading and weighing carefully what the makers have to say of their goods,—their engravings precisely represent what they are selling current in the market and describe in full all the merits claimed.

Fig. 361 shows a simple form of trap used on refrigerator outlet pipes to prevent a needless change of air in the interior, which would melt the ice all the faster. It also prevents sewer air from entering, when through some defect of work or fixture, it finds its way into the refrigerator waste. **S** is a sectional elevation and **T** a plan view; the trap slips up over the ice-chamber pipe and hangs on two lugs projecting into return slots, one of which is shown in the sketch. A refrigerator waste pipe should never be connected to a plumbing waste,—the discharge is not regular and

would not keep a trap sealed; such wastes should discharge over a fixture or cesspool.

Fig. 362 is a gravity hinged cover used on safe and tank overflow pipes to prevent mice and rats from passing, keep wasps and dirt-daubers from building in the pipe, etc. It is made to calk in, to solder on, or slip over and attach by set screw. Every precaution should be taken to keep foreign matter of all kinds out of water storage tanks.

CHAPTER LXX

How Water Trap Seals Are Lost

Fig. 365 is a common trap with vent. The dotted line **A** is the branch waste-line vent and **B** the main vent or stack. The seal could be lost by leakage through the wall, in this or any trap; if the trap and vent are clean and perfect it can still lose the seal by evaporation of the water, capillary action, syphonage, etc. If lost by evaporation the vapor goes out through both the fixture opening and the vent. The sizes of the piping and manner of connecting it affect the rate of evaporation. The vent in large traps should be at least 2-in. diameter. For 2-in. traps the vent should be $1\frac{1}{4}$-in., $1\frac{1}{2}$-in. or 2-in., according to the kind of connection and how far the vent can be carried vertically directly over the trap. No vent should be made less than 1-in. for $1\frac{1}{4}$-in. traps; $1\frac{1}{2}$-in. traps are better than $1\frac{1}{4}$-in., as a rule, for small fixtures.

It has been argued that small traps and pipe cleanse themselves better than larger sizes on the same fixture would; this is true within limits, but indiscriminate application of the idea by the mass of workmen is bad and the result shows how careful one should be in stating the limitations of a practice found safe under certain conditions, and, if the limitations are not known, at least the conditions under which a departure has succeeded should be carefully outlined. A bath, lavatory or fountain, with a small waste, conveying no grease will scour the surface of the pipe and prevent accumulations with better effect than a large pipe, but there are other considerations; the larger trap holds more water and will retain the seal longer, there is less chance for burnt match ends, pins, etc., to get wedged in the trap in a way to retain hair and lint, and the chances of flooding the vent above a bend are less with a large trap and pipe.

The large trap and waste, with vent in proportion is unquestionably better for any fixture through which grease may pass. Grease and water repel each other, and grease, with waste water, is forced to stay on the surface of the water. This means that when grease and water, together, pass into a waste, the grease stands between the water and the pipe wall where it is soon chilled to a paste and rubbed, by the pressure, into contact with the interior of the pipe,—there it stays. In this way, a vertical pipe is reduced in bore by grease building inward, layer by layer, until it is completely closed (the smaller the quicker). A horizontal pipe carrying grease forms ridges along the sides of the pipe at the normal water level. These build out into the bore of the pipe until their overhanging weight, not sufficient alone to overcome the tenacity

of the mass, aids the force of passing water to break them down, more or less, in places; lumps thus detached are swept along by water until they strike a restriction so made; the obstruction so begun, possibly welded by banked warm water or through jamming by the current force soon completes the stoppage.

It is apparent from the foregoing that even when a fixture passes only clean water, it is not sensible to use the smallest size pipe and trap that will answer when all is new and in good condition. A plumber who is a specialist in "roughing in," setting fixtures or doing supply work, (men versed in only one branch of the business thrive only in the larger cities) or indeed any plumber who has worked only upon new jobs, is not in a position, to pass upon, from experience the merits of this and many other questions of the trade.

If a crown connection is too small it chokes easily, even if vertical, and if there is a short turn in the vent below the level of the fixture overflow it may not only choke, but will choke with less provocation than a larger pipe. Fig. 366 illustrates, at **N**, a stoppage from overflow above the bend in a vent made too short and close down to the crown of the trap. These stoppages are seldom "tight" enough to thwart the purpose of the pipe, and a reasonable amount of foreign matter so lodged is sometimes an advantage in that it reduces the rate of trap seal evaporation.

Fig. 367 shows a mass of hair and lint saddled over a needle lodged across the bore of the trap. Many articles besides needles are apt to so stick in a trap, especially if the trap is of small size. Such obstructions are the beginning of an accumulation that becomes sponge-like in that it lifts the seal water by capillary force, and when saturated drops it, drop by drop, into the waste pipe. The normal water-level is at $\mathbf{O}$, $\mathbf{O}^2$. When the water is lowered to $\mathbf{O}^1$, air from the waste pipe begins to enter the room. Loss of seal from this cause may take place in either vented or unvented traps of any form.

Fig. 368 illustrates the effect of discharging fixture water through an unvented trap barely large enough to take care of the overflow. The trap and a portion of the waste pipe is filled with water when the fixture becomes empty; the water is in motion, with the speed due to gravity; velocity and molecular attraction are strong enough to keep the water intact against the force of gravity tending to break the column; if the trap was vented at the crown, atmospheric pressure in the crown pipe would counterbalance that at $\mathbf{P}^1\mathbf{P}^3$; gravity would then act to pull water down into the trap as strongly as it would to pull it down the waste and the column would be broken in the crown of the trap in time to save the seal; if the trap was larger than the fixture discharge could keep filled, the chances are great that the trap would never be so syphoned; but, if the trap is filled as shown, the cohesive force of the molecules causes all

the water to be drawn out,—an example of common syphonage, the long leg of the syphon being **P**[3] to the crown. The normal water line of the trap is **P**, **P**[2]. Gravity and unbalanced atmospheric pressure and their consequences are the causes of syphonage. With the conditions of

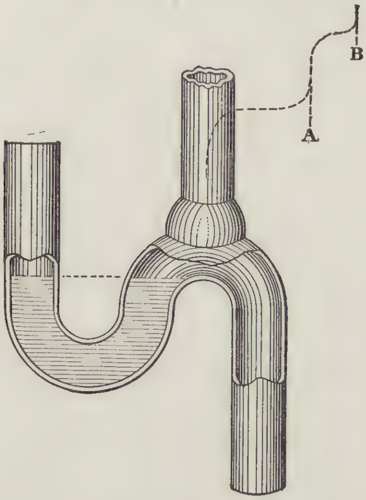


Fig. 365. Plain Vented Trap in Normal Condition

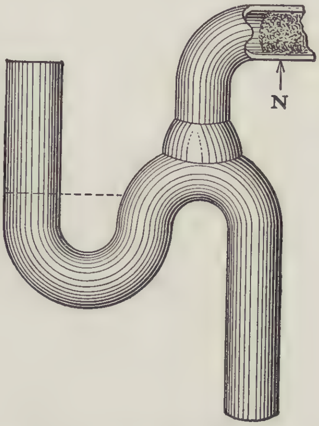


Fig. 366. Stoppage in Low Vent, Due to Overflow

Fig. 368, the air pressure at **P**[1] and **P**[3] is equal and there is no air pressure at **P**[2], so the extra weight in leg **P**[3] pulls the water out of the trap just as the long end of a cord would be followed over a pulley. Gravity

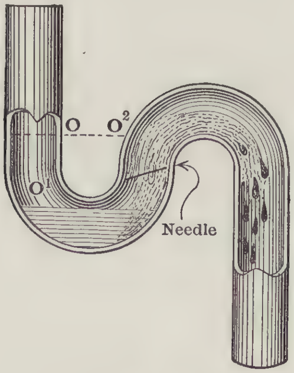


Fig. 367. Loss of Seal through Capillary Seepage

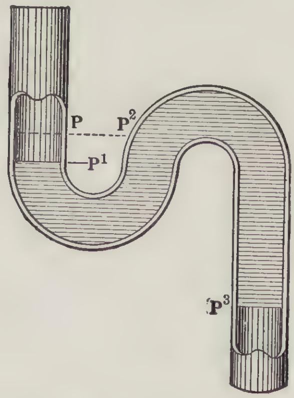


Fig. 368. Syphonage from Discharge of Fixture Water through Trap

and motion of the water produces the conditions favorable to syphonage in a case like Fig. 368 and gravity, through the aid of cohesion completes the action.

Syphonage of an unvented trap accomplished under conditions different from above is illustrated in Fig. 369. Water from a fixture, falling through a stack, generally takes a swirling course and the mass is usually well broken up; this may be observed by watching water fall in a glass pipe when injected from a branch somewhat as branch waste water enters a stack. Unless the discharge is very heavy, seals of traps connected below are seldom thrown much out of level from air pressure

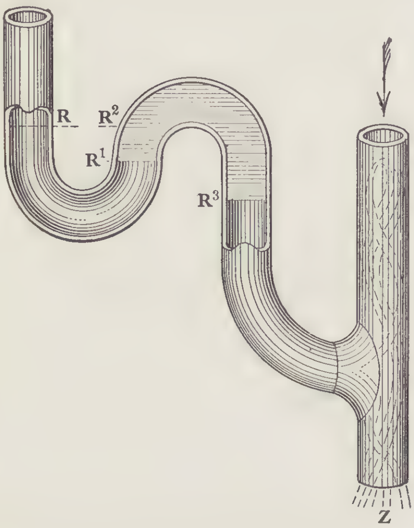


Fig. 369. Syphonage from a Fixture Discharging through the Receiving Stack

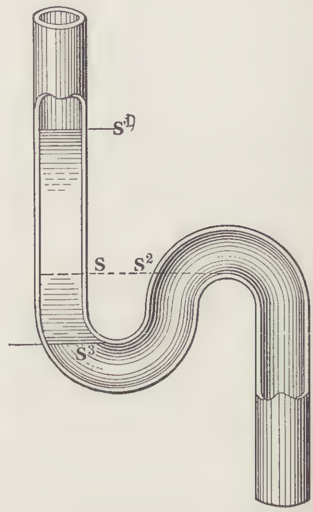


Fig. 370. Conditions for "Waving Out" of Seal,—Due to Sewer Pressure

in front of the water, but the spray and films of water cross branch-pipe openings in a way to suck air from the branch lines; if the branch lines are not vented in any manner, a partial vacuum is formed on the sewer side of the trap seal and the lack of balance to the air pressure of the room thus created depresses the water in the trap on the house side. If the rarification of the air on the sewer side continues and is rapid enough, the trap seal may take the position of **R**^{1}, **R**^{3}; when point **R**^{3} is below the level of point **R**^{1}, common syphonage occurs, the same as described in connection with Fig. 368.

Fig. 370 marks a trap seal lifted from normal, **S**, **S**^{2}, to **S**^{1}, **S**^{3}, as the result of pressure on the sewer side. This can happen from falling water in the stack driving trapped air before it; from an overcrowded house sewer during a rain storm where the stack is serving as a leader (it should not) and, from storm water compressing air in unvented lines. When the conditions of Fig. 370 exist, the water, in regaining its level, may acquire momentum enough to wave out sufficient of the water to break the seal, if the compression is relieved suddenly enough. The

author found one job in which the seal, from the compression mentioned, was ejected through a lavatory bowl with such force as to spatter the ceiling of the room 7 feet above bowl.

While preserving the seal by preventing syphonage, a crown connection increases the means of evaporation of the trap seal,—not greatly, it is true, when the connections are proper, but quite seriously unless provisions for securing slow evaporation are embodied. Fig. 371 is a broken view of a common vented trap; **Y**, $\mathbf{Y}^2$ is the normal water level; the capacity of 2 lin. in., as from **Y** to $\mathbf{Y}^1$ and $\mathbf{Y}^2$ to $\mathbf{Y}^3$ must be evaporated from this or any other similarly formed trap before the level of the seal water is lowered 1-in. The dots above the water surface represent water vapor, formed by the heat of the room or trap water. Vapor is given off regularly on the house side, in all forms of traps. The amount taken away on the sewer side depends upon the use and kind of fixture, size of trap, temperature of the house and style of venting. If a vent is of lead or other non-corrosive material, the crown vent can be reduced at some point above the fixture overflow level so as to greatly reduce the column of air passing through the vent; this reduces the vapor loss proportionally, and, with the sluggish current due to previous division of the vent air in the lines should preserve the seal of a common trap over any reasonable period. The vent in Fig. 371 is connected to the center of the crown. A little less vapor will be carried out if it is entered somewhat to the right of the center, making the waste and crown connection pipes more nearly in a straight line. For apartment houses where one part may be vacant while the balance is occupied, deep seal traps, traps holding a large volume of water, or with water and gravity mechanical seal combined should be used. A common trap with extra water depth is indicated by dotted lines at **T**, Fig. 371.

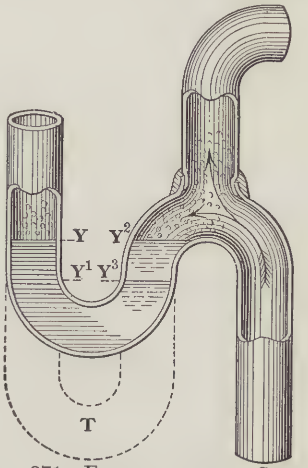


Fig. 371. Evaporation of Seal and the Means of Prolonging a Safe Water Seal

Sediment pipes from storage tanks entering the waste below fixture traps are sometimes a source of odor, from sewer air passing through the sediment pipe and cock into the room while the supply system is drained and the sediment cock and other channels open. In ordinary contract work the temptation to enter the sediment below the trap, as at $\mathbf{U}^1$, Fig. 372 is strong because the trap of the sink is often too high to allow the sediment to drain to **U**, and it takes more pipe to reach a lower fixture; likewise, the expense of a bracket stand over that of the standard

floor stand deters the plumber from elevating the storage tank, though it would give better service in several ways if raised so the sediment pipe could be run almost as high as the level of the lower hole in the range heater. Specifications usually say "connect sediment with waste" and do not specify *how*, so any sort of connection meets the letter of the specifications. Position **U** is best for the sediment, not only because it is above the trap seal but for the reason that it offers a means of applying

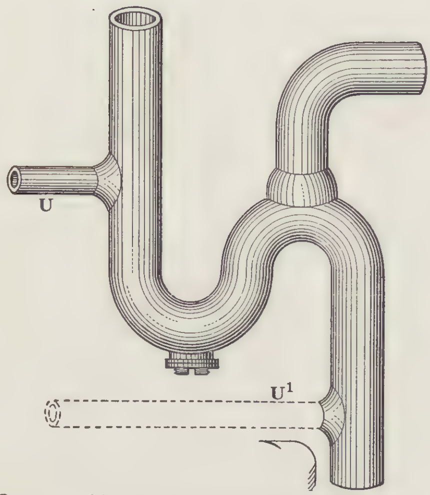


FIG. 372. WHERE TO ENTER SEDIMENT PIPES FROM KITCHEN TANKS

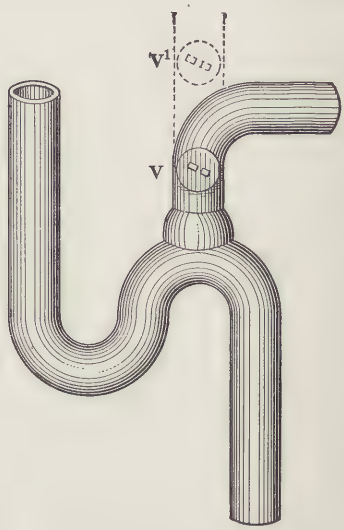


FIG. 373. CLEAN-OUT TRAP SCREW IN VENT PIPE

the water pressure to the trap as well as the waste, to force out chance obstructions,—by holding a cloth, putty or force cup over the sink strainer while the sediment cock is turned on. Cleansing the storage tank thus may load the trap with scales of mud and iron rust caked hard. So, after cleansing a tank by flushing, the trap screw should be opened and the trap cleaned:—sometimes a mass of stuff that did not come from the tank, and that would soon cause stoppage, is also found in the trap.

When Crown connections must turn short close to the trap it is a good plan to solder a trap-screw into the vent at some point accessible when the pipe is in place,—above the bend is best; at **V**, Fig. 373 will do. The condition of the vent can then be examined at any time, and cleansed, if necessary. In some jobs a capped connection is piped from vent lines to the wall face above the fixture as suggested by **V^1**. The inside of the ferrule is threaded for the male end of garden hose couplings so that water pressure can be applied to cleanse the vent of any foreign matter that may find a resting place.

Fig. 374 is a sectional view illustrating the principle oi traps with interior weirs and dips. Some traps of this type are non-syphoning but they offer two chances for sewer air to enter the house without betraying the defect by outward water leakage. They may also lose the seal by capillary action. The "dip" may be imperfect and allow air to pass, as at **W**, or the water weir may leak the seal into the waste pipe as shown at **X.**

From the foregoing, it is seen that fixture traps may lose their seals in six different ways,—through lack of a vent, by failure of the vent, by capillary force, through pressure on the sewer side, by evaporation, and by leaking weirs. The sketches show nine causes that may break the seal. Four of the six possible ways of losing the seal apply to Fig. 374 class; any of the four conditions may occur; none of them are absolutely preventable; five ways apply to the other traps shown and three of them are preventable.

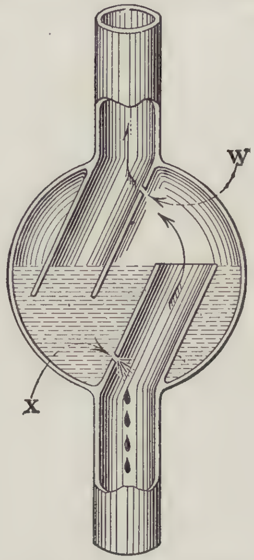


Fig. 374. Leakage through Interior Weirs

Probable Periods of Seal Evaporation

That the current of air through a crown connection does not, as before stated, rob the trap of the seal water as fast as is generally supposed, is certain. There is little definite data to work on but it will not be amiss to go into the subject a little further. Theoretical deductions made as follows give some idea of the evaporating power of various conditions:

The general annual U. S. range of evaporation from water surface in the open air is 22 to 58 in., according to location, with a mean annual loss of about 43 in. depth. The general average of wind velocity for the United States is about 10 miles per hour. The evaporation of water exposed to a current of air with a velocity of 10 miles per hour is nearly four times as rapid as the rate for "quiet" air. Eleven inches depth loss per annum may be assumed to be the rate for calm air.

With 20 deg. difference between the stack and outer air, the average 4-in. stack would give about 250 ft. velocity per minute,—15000 ft. or about 3 miles per hour. A loop stack dividing the up flow would pass 5000 ($\frac{1}{3}$ for the wet stack) lin. ft. per hour up the wet line. With three vent branches leading to one 2-in. connection in the wet stack $\frac{1}{4}$ (4-2 in. =one 4 in.) of this would pass through the manifold vent line, which, divided by 3 would give 416-ft. per hour of 4-in. pipe capacity of practically equivalent to the conditions of "calm" open air so far as velocity

is concerned. This would warrant the assumption that a 1-in. "drown" or 2 in. depth to lose to break the seal, would, in a common trap, with the fixture outlet closed, insure the trap remaining sealed for 60 odd days. A deep seal trap would go proportionally longer without replenishing the water, whatever the actual time might be. The retention of the seal is further favored by the high humidity of the air passing to the crown vent,—it having been in contact with wet surfaces and so become loaded with vapor; also the dry vent stack, horizontal run and fixture stack are frequently of the same diameter, thus beginning the division and redivision of air in the branch lines with a greatly reduced velocity as compared to that at the vent exit.

Taking the capacity of a 2-in. crown connection to be $\frac{1}{5}$ the capacity of a 4-in. stack, the crown line carriage (if there is but one) will in a loop stack be about $\frac{1}{15}$ of the stack air, and as previously indicated this small share stagnates the velocity in the crown vent to a comparative calm over the water in the trap,—good reason for assuming that the rate of evaporation in a common residence trap would not be far from the average for quiet atmospheric air of lower humidity.

The probability of loss of seal may be considered from another point of view worthy of attention. Take a 25-ft. stack with 15 ft. exposed to 70 deg.; 20 deg. difference, and, say 200 ft. per minute velocity or about 1000 cu. ft. per hour stack delivery and 50 per cent. initial humidity to saturation, (the average initial humidity is much larger). Assume that $\frac{1}{10}$ of the $\frac{1}{15}$ stack capacity passing the crown vent gets into position to grapple the vapor over the water in the trap to the extent of saturation; then something like two ounces per day would thus be carried out, provided the temperature of the house was high enough. The seal would in this way be broken in a 2-in. common trap in 3 to 4 days, the shortest time possible, perhaps, under any probable residence conditions ever existing in temperate latitudes. A 4-in. common drum, or non-syphon trap with $1\frac{1}{2}$-in. vent would remain sealed under the same conditions, from 20 to 30 days, assuming perfectly clean vents.

The amount of vapor taken up by crown vent air grows less as the level of the water in the trap is lowered by evaporation. With air of high humidity passing through, say from the public sewer or a marshy suburban exit, the seal would, on the last basis mentioned, be prolonged, in some cases, to three months or more in a common trap. One instance of record shows a house had been locked for 80 days,—in cool weather, after which period, the lavatory, bath and tray traps were found to contain 80 per cent. of their figured capacity.

If the premises of deduction be confined to the trap heating surface required to evaporate the water, and extreme conditions are assigned, it works out as follows: Take a 4-in. common lead trap with 0.8 sq. ft.

surface in contact with seal water; 3 pounds of water contained: evaporation 1 lb. being sufficient to break the seal; conductivity of lead half that of iron, and 1000 B.t.u. taken to be required to warm the trap and vaporize 1 lb. of water. Under these conditions the seal of a closet trap would be broken in 3 to 4 days and the trap dry in less than two weeks. Average, and favorable conditions would prolong the seal period to accord with other periods already premised.

It is probably that with cold seal water and very humid warm air, the seals of traps are sometimes replenished to some extent by condensation of vapor from the vent air, much as "dew" ponds are said to derive or retain some of their supply. It is certain that dry vents, branch waste vents and crown vent loops all divide the stack delivery and prolong the seal period more or less according to arrangement.

CHAPTER LXXI

Fixture Connections

The greatest care in piping main lines of soil and vent pipe will be of little avail unless the fixture connections also do their share in protecting the house from sewer air. If the traps used are of the non-syphoning type, vent work ends with the proper ventilation of stacks and branch-waste lines. If common open wall traps in any of the many forms are used, protection against syphonage of the seal-water must be provided. Mere prevention of syphonage is not adequate for that object can be accomplished in ways that still leave deplorable conditions.

The man on the job will always be the prime factor in securing good work, and while he may truly feel that no aid in the shape of plans or advice can come from any source superior to himself, he will need and generally welcome in the interest of his own and the trade's advancement, any real aid that can be handed to him through the dear experience of others.

If one knows a certain means of securing a desired result, let him beware of discarding that means for another about which he personally knows little. Either halt until self-convinced from personal investigation, or at least until the source of the innovation is found to be thoroughly reliable. That the other fellow's way is not wrong, within limits, is not enough to be sure of,—your way may *also* be *right*, within limits, and within limits that give a wider field of application, too. You may know much about the general application and effect of your way, and both yourself and the man with the new way may know little about the ins and outs of the new way, and too, he may know of weak points that he does not mention,—so, be reasonably sure of the result, before you change practice simply on the other fellow's word. In the following is pointed out some of the merits and demerits of different styles of fixture waste and vent work, with reference to preserving or destroying the trap seal.

Crown vents were originally intended for the specific duty of preventing syphonage of trap seals and should never serve any other purpose. Mistaking the function of the crown connection by literal interpretation of the misleading trade term "crown vent" has without doubt been the cause of not a few of the unsatisfactory experiences with *syphon vents*, the bad behavior of which has incidentally provided a foot-hold for attacking a safe system of venting. How to insure its purpose being fulfilled, therefore needs defining and the conventional sketches in Fig. 380 are intended to aid in describing clearly the use and misuse of

"crown" connections, the effect of not employing such where needed, and also to show certain conditions under which they may be omitted. The points **AAA** are to be considered as above the highest fixture on the stack.

Inherent conditions favoring syphonage are present in No. 1. There is neither stack vent nor "crown vent." Under such conditions, a non-syphon trap should be used instead of the plain type. Installed as shown, if the fixture discharges its water freely, the outlet of the trap will become the long leg of a common syphon and empty the trap of its seal water nearly every time the fixture is used.

Conditions for syphonage are also present in No. 5. It shows a stack vent, but there is no crown connection to the trap and no branch-waste line vent; therefore, the trap is on an unventilated dead end,—if sealed; if not sealed, the trap is useless and its mission being an important one, the work is radically defective. Any non-syphoning trap would give better service than a plain trap so connected, because syphoning would be prevented by the non-syphon trap, while the other merely affords a false feeling of security to the owner—the meanest type of deception.

If a common P-trap is connected directly into a stack, like in No. 2, it is not likely to be syphoned by fixture discharges even though the stack be the same size as the trap; but a $\frac{3}{4}$-S trap or a P-trap with an inclined outleg dipping enough to bring the top of the outlet well below the bottom of the crown, somewhat as the trap in No. 4 shows, especially if it be placed a little further from the stack and the out-leg extended normally, will ordinarily syphon regardless of the size of the stack. If the trap and connection is larger than the fixture outlet can keep filled, the trap will not syphon. These facts have been long taken advantage of and have also been the basis leading to much poor work in the shape of plain unventilated traps being placed so far away from the stack that the fall required in the connection brought the end of the outleg too low, —low enough to form a common syphon of the outleg of the trap, counting the outlet end and trap branch connection together as the outleg.

These cases are not numerous, but the serious practice of using unvented plain traps discharging to under-floor lines is general in some towns,—the result not of ignorance on the part of the trade, but of indifference in the Inspector's office, controlled and filled by politicians without consulting the best interests of the trade and public through proper coöperation with the trade.

No. 3 shows a common form of drum trap. No vent is indicated, but with the drum connected to the pipes as it is (to put the sewer air against the water seal in the connection only instead of against the drum water surface and clean-out gasket), it should be vented unless close connected. There are strictly non-syphoning traps of the same gen-

eral appearance suitable for connecting the fixture to under-floor lines without venting. Such traps may be placed above the floor as indicated by the dotted trap form in No. 4.

No. 6 presents no inherent conditions favoring syphonage, but the arrangement will cause a relatively rapid loss of seal. While all the vents are embodied in a literal sense, there is no stack vent proper; no branch-waste line vent proper, and the crown connection does not join a party stack vent,—it is by this plan made to do duty as a stack vent, branch-waste line vent and syphon preventer, a triple function, to none of which it can so do justice and through which the whole current to the roof (through the stack, branch-waste loop or whatever the lines happen to be) is brought into close proximinity with the seal-water of the trap,—conditions for evaporating the seal in the least possible period of time. The missing part of the incomplete stack is indicated by the dotted line.

Connections like shown in No. 7 are frequently seen in practice. Such, with a non-syphoning trap would be first class; with a plain trap, syphonage is not taken care of; the stack is vented; the branch-waste line is vented, and the current up the branch-waste is thus diverted without giving it a chance to load itself with vapor from the trap seal water, but syphonage will take place, and therefore the other good points lose much of their normal value as the result.

In No. 8, the crown vent is provided in a way that makes the syphon vent do duty also as a branch-waste line vent,—this is much like No. 6, though better because the branch-waste line carries only its part of the air, and that brought close to the seal water would be humid from its previous travel over wet surface. No. 8 would generally be considered fair practice on the main lavatories of residential work, even with shallow seal traps, and if deep-seal traps be provided, there is little objection to it being followed in other locations where the use of fixtures is quite regular and the seal therefore not likely to be absorbed during intervals of disuse. It also does very well with a shallow seal trap where one trap serves a battery of lavatories or trays.

No. 9 provides a crown connection, branch-waste line vent and stack vent,—the branch-waste line vent being a vertical continuation of the branch-waste, so that no lodgment of foreign matter or corrosion can occur. This manner of piping offers a course of least resistance for the branch-waste vent current through the proper channel and results in the minimum amount of air being carried through the trap waste and thereby into juxtaposition with the trap seal-water while entering the crown connection. The least possible absorption of trap seal-water vapor is the result. No better arrangement of venting can be provided for ordinary work.

It follows from what has been said, that short connections should

enter a vented stack direct, without appreciable drop; that the area of traps and connections should be larger than the area of fixture outlets; that the syphon vent should have no other duty, should be supplied with air from a branch-waste line vent, enter the *crown* of the trap,

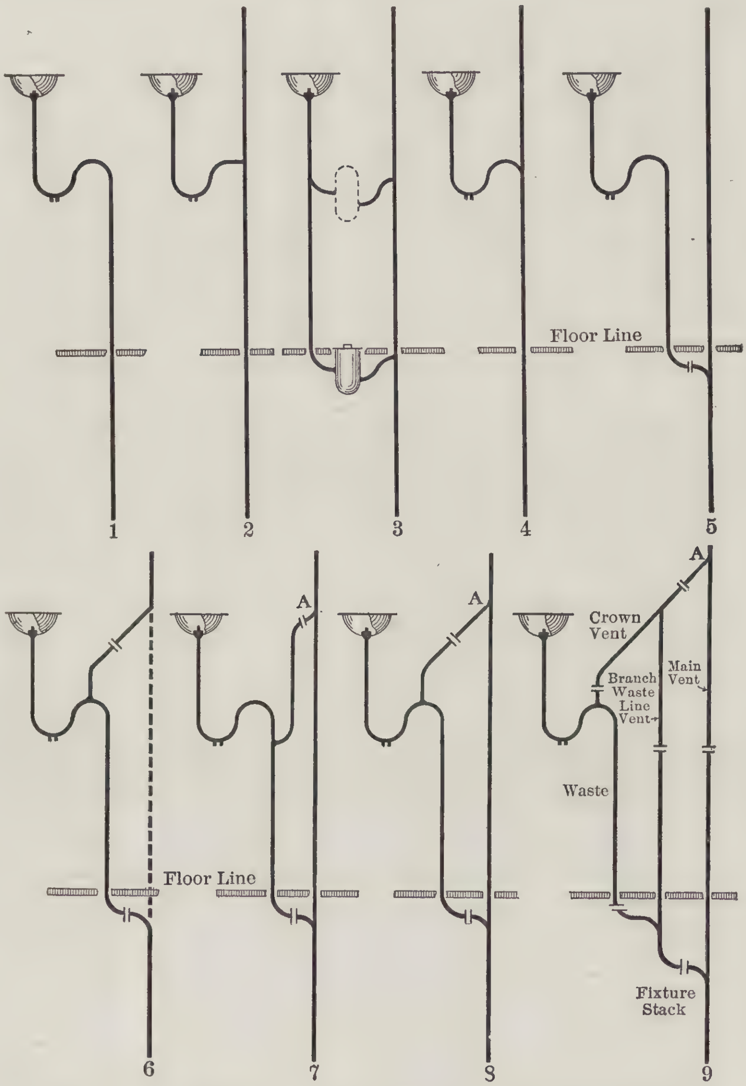


FIG. 380. FIXTURE CONNECTION AND BRANCH-LINE VENT PIPES,—CONVENTIONAL LAY OUT

and take a vertical course to above the fixture overflow level if possible; that all vents should be arranged to discharge foreign matter where it will be washed out of the system; that non-syphoning traps should be

used where it is impossible to properly vent other kinds; that non-syphoning traps may be used generally; that all vents except the crown connection is as necessary with non-syphon traps as with any other; that sewer air should be excluded from buildings and that it may enter through chance leaks contingent upon settling, shrinkage and defective workmanship, flaws in materials and general deterioration. It should be remembered too that the safest trap for general use is the open-wall plain trap,—it is of logically correct and proved-by-experience shape; has the minimum of fouling surface, all self-scouring; has total walls exposed and no interior weirs or dips that may leak in the beginning or become defective without betraying the fact and thus "leak" the seal into the waste or pass sewer air by it into the house,—in short when properly installed an effective safe-guard in the fullest sense, that betrays leakage of seal instantly, but with which must be used the crown connection necessary to prevent syphonage from unbalanced atmospheric pressure. Other vent lines mentioned are proper for any form of trap, and the recommendation of such is based on sound, well-supported unrefuted principles.

The author does not wish it understood from anything said that he condemns non-syphon traps; they are safe and effective in competent hands; the door is open to them; they are generally specified for the locations they were designed for; the makers do not complain of any prejudice against the proper use of them and the desirable trade recognizes the merit of such goods. In fact the U. S. government, specifies non-syphoning traps,—not to save venting expenses, but because the conditions of its buildings lead the designer to believe such traps will give the best service.

Where "inherent" conditions for syphonage were referred to it was for the purpose of distinguishing syphonage due to the character of the connection from that caused by capillary action through lint, and by air pressure on the sewer side, etc.

CHAPTER LXXII

Testing Soil and Drainage Work

Although testing work is an important feature of every reliable job, it needs but a brief consideration, for every good mechanic knows that defects are limited to two classes—to those of material and workmanship—and is as well acquainted with the range and character of the first as he is with the prevention and remedies of the second.

Every reasonable endeavor should be made to detect imperfections in the goods prior to use. No made up section of piping, or fixture, should be placed without searching for weaknesses, errors and defects or workmanship. There is a great difference between the cost of this plan and that of "slamming" the work in with a lick and a promise and trusting to luck that it will prove O.K., for there is much needless expense in pulling out bad material to put in good, and breaking out good material to get rid of poor workmanship.

Besides such preliminary tests of loose goods as may be resorted to as a precautionary measure, the regular course is to test the "roughing in" work, and then the finished job. Where the water test can be applied, the safest form if preliminary test is to follow up the work with a water filling thus always having all of the stack and laterals under test as they grow. This plan is adopted for sections of big jobs that are afterward connected up for the general "roughing in" test applied in the presence of the inspector. In tall buildings work where the water pressure on the stack, if filled from top to bottom, would be excessive, the stacks are often divided into sections, not alone on account of pressure but that more men may work at once. Where there was no occasion for more than one crew on the work of running up a stack, 25 or more stories have been built up on wrought work with the water following as fast as the work was built in.

Four kinds of tests have been practiced, viz.: water, smoke, air pressure and the peppermint. The characteristics of the water test are: the pressure is proportional to the altitude,—sometimes excessive on the lower parts; damage may result from water leaks; in severe weather it is unsuitable unless the freezing point of the test water be altered, say with chloride of sodium or calcium. The water would then be safe for ordinary tests to zero weather but would have to be pumped or poured in. While these traits are detrimental to some extent, the water test, though necessarily confined to "roughing in" on account of the pressure, is ample, can be easily applied in most cases and the leaks are quickly, surely and easily found.

The peppermint test, though official in some cities, would generally be a laughing matter was it not so often a misleading substitute in serious work. It is good for detecting leaks in hidden work under floor or underground, and will do very well for a finished work test where a safe "roughing in" test has already been applied. For house testing the practice is to pour *oil* of peppermint into the stacks and follow it up with hot water to vaporize the oil. For a residence job one ounce of the oil may be thrown into each stack, and vent that reaches the roof, and a gallon of hot water poured into each and the stack closed after a few minutes. If the vents are assembled into one stack, 2 oz. of oil should be used. As the leaks are traced by the odor, the person handling the oil should not enter the building if it is turned loose at the top of the stack in the usual way. Briefly this method is of little value, produces no pressure in the pipe, is suitable for use in any climate, does as well for "roughing in" as for finished work, and does no damage to work or building.

The smoke method is ample for a low pressure test, and as such is generally applied to finished work because trap seals prohibit the employment of more than a few inches of water-gauge pressure in finished jobs. The smoke test is effectual for "roughing in," only so far as the limited pressure will evidence a leak. It gives uniform pressure, can be applied in any season in any climate and does no damage. Leaks are evidenced at the machine by the drum settling in the water or the water falling in the gauge, and are detected in the work, usually by the sight of smoke, but generally with soap suds applied with a brush where the leaks prove to be small.

Some inspectors make trouble by maintaining that the drum or gauge should stand indefinitely at the mark pumped up to, seeming not to know that the air and smoke were forced into the pipe warm. For coolage, $\frac{1}{460}$ of the unit volume of the system per degree F. difference between the temperature of the gases pumped in and that of the main stack contents at the end of the test is allowable for the total cubic settling of the drum during the test, provided no evident leakage has contributed to lowering the drum. If the gases in the system are allowed time to assume the temperature of the outer air and pipe, the drum *will stand*,—if there are no leaks. The smoke method is destined to give place to simple pressure tests. In some localities the machine is now being used as a pressure pump without regard to the smoke feature. This eliminates the question of shrinkage of contents in the system and the allowance therefor.

There are various makes of machines in the market, all meeting the same requirements in one way or another. The essential features are a small gasometer, water sealed and containing a grid upon which a

quantity of oily waste, oakum or rags or tarred paper is burned slowly in a deficiency of oxygen so as to make dense smoke in sufficient volume to fill the pipe system. The space in the rising drum is arranged to connect by hose to a soil pipe plug; the air supply for burning the waste and creating the pressure is drawn from the open through a suction valve; the products of combustion pass through the hose into the pipe; the pressure of flotation is registered by a glass water-gauge. The pressure can be increased by weighting the drum, but must be kept so low that trap seals will not be blown out. Smoke is pumped in until it issues at the roof, before closing the vent. Clean-outs or plugs should be removed on all long laterals until they fill, for if the sight of smoke is desired to locate a leak it may otherwise take unnecessary time for the smoke to diffuse in laterals and to fill the blind ends.

Many plumbers now use sulphuric ether to detect leaks,—pumping it in with the drum of the smoke machine,—this is better for odor detection than is peppermint and is gaining ground against both the peppermint and smoke methods. The ether should be put in at the pump,—never at the top of a stack.

For searching after and accurately locating a leak in places not readily accessible, there is nothing better than a clean glass tube. Glass has no odor peculiar to itself and a tube can be thrust down between floors and the end made to trace around the joints while sniffing at the other end. In this way the particular joint and section of it, as well as cracked hubs have been determined before flooring was removed and in some instances leaks have been calked with long bladed tools without removing the floor.

In view of what has been said it is evident that simple air pressure is the best means of proving whether there is leakage. Air carrying the fumes of ether under pressure is the surest way of approximating the location of a leak. Soap suds will discover the minutest escape of air. It makes no difference whether the pressure is produced with a smoke machine drum or a gas pipe proving pump. For the finished work test use a water gauge showing 2 to 4 in. pressure. The column should remain at the same level for 15 or 20 minutes, before a line is presumed to be right. If air pressure is employed on "roughing-in," a mercury column should be used, and the column pumped up to about 20-in. high. In warm weather, the pump should be set in the cellar where it will take in cool air,—if warm air is pumped in it will shrink more or less and let the column down accordingly the same as though air had leaked out. The details of conducting air tests are too well known to need a detailed description.

The preparation for testing on cast pipe work consists of expanding test plugs made for the purpose in the hubs or pipe ends. In these

plugs two discs are brought one toward the other, by a long screw so as to arch a rubber ring in a way to increase its diameter and so form a packer in the pipe. Lead pipe ends may be soldered closed, or, by using a metal sleeve over the outside to keep the pipe from spreading, the usual test, plug can be expanded in the end of the lead for 2-in. and larger. Wrought pipe is usually closed by screw plugs or caps, but expansion plugs are used more or less, especially at the pump end or water inlet point.

CHAPTER LXXIII

Roof Flashings

It is only necessary to scan the roofs in any vicinity to see that the work of flashing around vent pipes is too often done without the skill that should be displayed by one that takes pride in his work. Lead makes the best flashing for most plumbing purposes; its fashioning is within the scope of plumber's work; he is familiar with working it, and no skill is required that the plumber can not bring to bear, though pipe flashing is often looked upon as a tinner's job, principally because he has given the cutting and fitting attention enough to make his work look well, and without wasting material.

Telling the story is a tedious job and the lines of roof pitches and patterns look complicated enough to discourage a beginner, but the sketches are easily understood and the actual work can be done, with all the accuracy necessary, with half the show of pattern development needed to explain *how* and much quicker than it takes to tell about it in a way that will carry understanding to the reader.

The "pitch" of the roof is the first essential, when a flashing is to be cut. If a roof is practically flat, a deck flange with equal flare is quickly snipped out, trimmed and formed, to fit the pitch without regard to regular methods, so far as the base is concerned, but the average pitch requires a well defined method to get a good result, and to know before hand that you will.

Roofs are framed with certain slants rising from the horizontal called "pitch." If the "pitch" is such that the comb (top of rafter or ridge-board) rises, to a height above the rafter plate equal to the width, by the time it reaches a point plumb over the center of the width, the slant is called "one-pitch." Any slant, less, is designated as a fraction of one-pitch,—as "$\frac{1}{2}$-pitch," "$\frac{1}{3}$-pitch," etc. One-pitch is the diagonal of two squares, as laid out in Fig. 385, **AC** being the rafter length and **CY** its vertical rise in half the width of the building,—**CY** being equal to **AB** and **AB** equal to the width of the building. For any roof with comb in center of width, the sides of the squares are equal to half the width of the building. Between **AC** (the rafter) and **AB** (the rafter plate) are included about 63$\frac{1}{2}$ deg.—a little steeper than the angle given by a 60 and 30-deg. triangle. A $\frac{1}{2}$-pitch (**AT**) includes 45 deg., is the diagonal of one square, and rises to half the width (**TY**) of the building by the time the upper end of the rafter is plumb over the center. A $\frac{1}{3}$-pitch includes about 33 deg., rises to $\frac{1}{3}$ the width is traversing $\frac{1}{2}$ of the width, and so on for other pitches, all about as set forth on the diagram

in Fig. 385, in which are all the little errors common to laying out such a diagram with a small protractor. No pretense of absolute accuracy in the text derived from the diagram is claimed, but it all is as correct as any workman will care to try to work to.

Many will recognize the roof slants as secants of the quadrant produced to intersect the tangents, and the rise or heights of roof to be, in each case, the tangent of the angle,—**AY** being the radius. From these functions the multipliers in the following table were derived:

Five-inch diameter flashing was assumed for convenience in giving the figures in the right hand column of Table XXX,—the minor axis of all the ovals would, of course, be 5 in. If the outside diameter of the pipe in Fig. 385 be taken to measure 5 in., the line **bb′** (major axis) would be 11.2 in. long; to get this length, the secant multiplier for one pitch

Table XXX. Roof Pitch and Flashing Multipliers

Standard Pitches	Degrees Rise	Tangent Multiplier, Inches	Secant Multiplier, Inches	*Major Axis of Pitch Oval, Inches
..	$5\frac{5}{8}$	0.0985	1.0048	5.02
$\frac{1}{16}$	7	0.1228	1.0075	5.04
..	$11\frac{1}{4}$	0.1990	1.0196	5.10
$\frac{1}{8}$	13	0.2309	1.0_63	5.13
..	$22\frac{1}{2}$	0.4142	1.0824	5.41
$\frac{1}{4}$	26	0.4847	1.1126	5.56
..	30	0.5774	1.1547	5.77
$\frac{1}{3}$	33	0.6494	1.1924	5.96
$\frac{1}{2}$	45	1.0000	1.4142	7.07
..	60	1.7321	2.0000	10.00
1	$63\frac{1}{2}$	2.0057	2.2412	11.20

*For cylinder flashing base for 4-in. pipe,—diameter of cylinder, 5 in.

($63\frac{1}{2}$ deg.), 2.2412 in., was merely multiplied by 5. Likewise, **dd′** would be 7.07 in. as given, being $1.4142 \times 5 = 7.0710$. The figures of the right hand column are of no value to the reader beyond showing how the length of a pitch oval the long way, up and down the roof, is obtained.

The multipliers are at unity in the table. For flashing purposes, for any pitch in the table, the tangent multiplier is the vertical rise in inches of the roof slant per inch of actual diameter of the pipe stack. Therefore, no matter what the diameter of a pipe or flashing may be, if it is multiplied by the figures given for the required pitch it will be the vertical distance, in inches, that the upper side is above the level of the lower side, both points taken at the plane of the roof. In the same way, the secant multiplier for any pitch is the slant length in inches on the roof plane from the low to the high side,—that is, from **b** to **b′**, or **d** to **d′**, as shown in the diagram.

To cut a hole, in roof sheeting for a vertical pipe, the outer diam-

eter of the pipe can be set off for width with the pipe center-mark bisecting it; the length of the oval, up the roof, found as already described, is then marked over the center-mark in the same way. Ordinarily the oval can then be penciled in free hand correct enough. If the pipe is large it is better to strike a string oval to cut by. A string oval is quite true if the string is one that does not stretch easily and the tension is

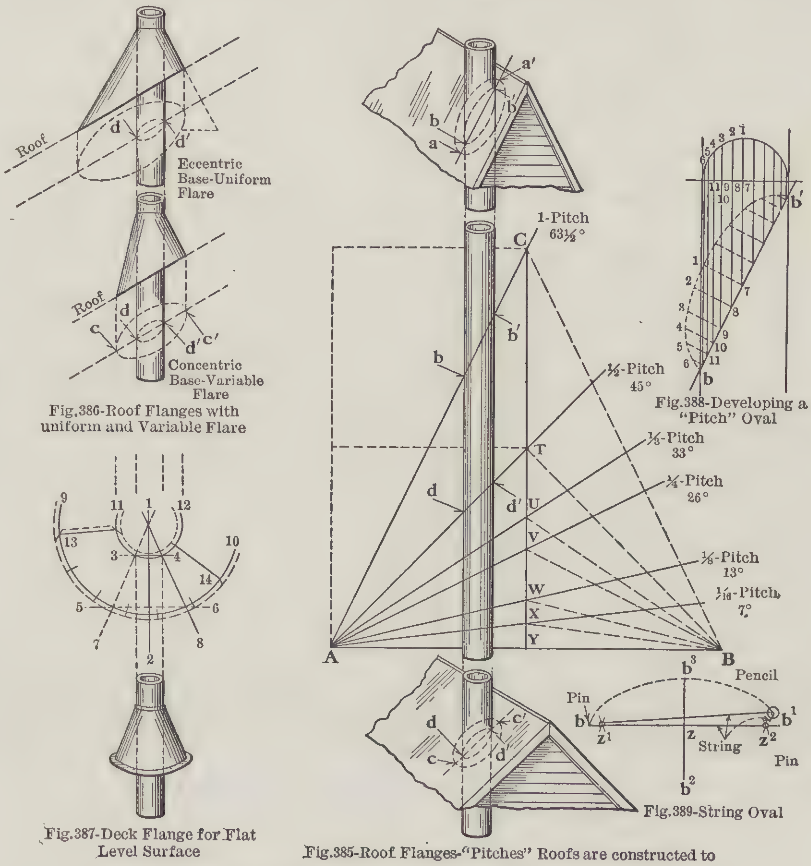


Fig.386-Roof Flanges with uniform and Variable Flare

Fig.388-Developing a "Pitch" Oval

Fig.387-Deck Flange for Flat Level Surface

Fig.389-String Oval

Fig.385-Roof Flanges-"Pitches" Roofs are constructed to

FIGS. 385–389. ROOF "PITCHES" AND PIPE FLASHING PROBLEMS

kept uniform when scribing. The manner of laying out, set forth in Fig. 389 is based on the fact that the aggregate length of any two lines, one drawn from each of the two principal foci of an ellipse to any one and the same point in the oval is equal to the length of the major axis. Therefore, to describe a string oval to given dimensions, set off the two diameters, bisecting each other at right angles, as shown by **b**, $\mathbf{b^1}$ (major axis) and $\mathbf{b^2}$, $\mathbf{b^3}$ (minor axis), Fig. 389. Then, with compasses set to half of the major axis, **bz**, and with $\mathbf{b^2}$ and $\mathbf{b^3}$ as centers, cut the major axis at both $\mathbf{z^1}$ and $\mathbf{z^2}$ from both centers; the intersections $\mathbf{z^1}$ and $\mathbf{z^2}$ are

considered the foci. Then with pins or small nails stuck in at **z**^{1}, **z**^{2} and **b**^{3}, tie the string so it will just reach around them, making a triangle with straight sides and with the corners at the pins. Next remove the pin at **b**^{3} and bring the string taut with the point of a lead pencil and scribe around, keeping the tension on the string as even as possible.

At the foot of Fig. 385 is shown a $\frac{1}{2}$-pitch roof, (45-deg. gable) with pitch ovals dotted on in perspective. **d-d′** is the pipe hole; **c-c′** represents the base oval of a flashing of uniform flare; the hole in the flat of the roof flange to which the flashing would join would fall somewhere between the two ovals indicated, as would the base of a cylindrical flashing. Over the diagram in Fig. 385 is a 1-pitch roof indicating the same ovals in the same way, at **b-b′** and **a-a′**.

The journeyman is not supposed to go through the antics of laying out patterns on the roof as needed. The object of presenting the diagram and other figures kindred to the work is to show that roofs are built to definite slopes and that flashing patterns for the different pitches can so be cut, once for all, in the shop, and a stock of flashings made up at leisure, ready for the busy season. Once familiar with a correct pattern, one can in case of an emergency, do a pretty good job of cutting by guess work if needs be.

In Fig. 386 are two diagrams. The upper one illustrates a flashing of uniform flare. The ovals at the roof plane in this fall eccentric to each other. This type of flashing is easy to cut, but suitable only for roofs of small pitch unless made with very little taper, and even then the lowside for $\frac{1}{2}$ and greater pitches is exceedingly long. The lower sketch shows a flashing with varying flare. The ovals at the roof plane fall concentric, in it; that is, at "pitch" incline, the plan view gives concentric instead of accentric circles. This shape is more difficult to develop, all told, but the triangulation work is simplified in that all the triangles of each set have an equal base length making but two triangle bases to the pattern. The letters on the bases in these sketches correspond to those on same parts in Fig. 385.

A deck flange or flashing with equal flare, for a level surface is shown in Fig. 387 in perspective; above it is the pattern diagram showing how to develop the shape,—a very simple pattern, easily and quickly set off on the metal on the job. Set off, parallel, separated to equal the height of the article, two lines, 3-4 and 5-6; erect a line 1-2 of random length, centered over these, perpendicular to them; set off on 3-4, half the diameter of top, and on 5-6, half the diameter of the base,—both extending from line 1-2, to right or left, say to the right; through the extremities of these half bases, produce line 1-8; this gives a half elevation of the article on the center-line. Where lines 1-2 and 1-8 intersect each other is the scribing center. It is a little more accurate to also produce the other half of the elevation and cut 1-2 with 1-7 and use the

common center of two intersections as a scribing point. Next, with compasses set in center, open them to where 1-8 crosses 3-4 and scribe 11-12; then open the legs wider so as to reach to where 1-8 crosses 5-6 and scribe circle 9-10; then, with dividers set to the radius of the base, take six steps on circle 9-10, beginning, say at 13, and ending at 14,—the portion of the circle 9-10 between 13 and 14 is equal to the circumference of the base of the article, and the circle is to the proper radius to make it form up to the required dimensions in a way to place the whole base edge in one plane and at the "pitch" angle to the top. Next, as all circumferences bear the same ratio to their diameters, there is no need to step the circumference of the top, on circle 11-12,—simply draw lines from 13 and 14 to the scribing center; the arc of circle 11-12 falling between these lines is the circumference of the top and the curve of the arc is proper to form a flat top edge setting level, when the base line is at "pitch" incline.

Add such edges as may be needed, indicated by dotted lines in the sketch, cut out and form up; the article will appear something like the perspective in Fig. 387 and agree with the dimensions of the elevation. The base and top planes must be parallel if this method is employed.

When there is occasion to cut a neat pitch oval, as in the case of the base hole in the roof flange of cylindrical flashings, the better plan for developing the oval as shown by Fig. 388. Set off the minor diameter of the hole; scribe a semicircle to it; step the arc into a number of equal spaces in a way to have one of the points come at the center of the semicircle and mark the circle at each step; erect and prolong tangents of the arc at the extremities and draw ordinates of random length, all perpendicular to the diameter and cutting the marked divisions on the circle; number the ordinates on one side from center to extremity, both on the diameter and on the arc, all as shown in the sketch; below the diameter, strike the pitch line, **b b′**; from it erect lines perpendicular to it from the points cut by the ordinates; on these lines or ordinates, set off in respective order the distances between the diameter and the circular arc on corresponding lines; ordinate distance 1 to 7 of the circle becomes the distance 1 to 7 of the pitch oval; 2 to 8 at the circle is the distance for 2 to 8 at the pitch, and so on. Each half of the oval being the same, each ordinate numbered at the circle is the measure for two lines of the oval, one on each side of the center at equal distance from it, except in the case of the center line, 1-7; the distance points so marked off on the ordinates struck from the pitch line (major axis of the oval) all fall in the line of the oval and the oval itself is produced by connecting these points free-hand as indicated by the dotted line in the sketch; the remaining half of the oval may be traced, or the ordinates made to cross the pitch line so as to be able to set off the distances on both sides of it.

CHAPTER LXXIV

Developing Patterns for Variable and Uniform Flare Flashings

A flashing of the proportions shown will serve to explain how to develop a pattern for a flashing of any dimensions or flare, but real flashings should be high enough for the top to stand above the snow line. The first step in making the pattern is to draw the elevation 1-0, 2-S, 1-2, 0-q^1, 1-0 equals the diameter at the top; 2-S is drawn at the pitch of the roof and is equal to the major axis of the pitch oval. Let the vertical height on the high side at 9-0 equal any height thought necessary. 1-2 is produced from 1-0 until it departs from a line drawn perpendicular through 1, a distance equal to the desired flare on the low side. If 2 in. is the flare then produce a line from this flare departure (point 2) parallel to 1-0 in the direction of 1, and 2 in. at the right of 0, erect from it a perpendicular line extending upward at random (**q-n**). Next produce the pitch line from 2 cutting line marked **q-n** at S. Then connect point S with 0 and the elevation is complete. Some may find it easier to begin by striking a half plan view of the top and base as shown above the elevation. However, to go on as begun, speaking first of the development of the pattern for a variable flare flashing:—erect lines from 2, 1, 0 and S, Fig. 390, perpendicular to 1-0; and, parallel to 1-0 set off **j-n**; from center of **j-n** strike semicircles from **j** to **n**, and from **k** to **m**. Step off **j-n** semicircle in spaces as shown, and from the divisions, **j**, j^1, 3, 4, etc., draw lines **j-k**, j^1-k^1, 3-3^1, etc., all radiating from the center; this at the same time divides arc **k-m**, proportionally, without stepping it. Tangential dotted lines j^1-**k**, 3-k^1, etc., are next produced. The radial lines j^1-k^1, etc., are all the same length and are the bases of the principal triangles used in the pattern development; the tangential lines are also all of the same length, though longer than the radials, and are the bases of a second, a secondary set, of triangles, similarly used. The altitude of all the triangles of both sets are marked on line 0-**p**, the apex of all being 0. The base length of the radial triangles, equal to **j-k**, and of the tangential set, equal to j^1-k^1, indicated at the bottom, are extended in solid line to **q** length at the right for the radials, while the bases of the other set are measured by the dots at **r** length. **j-k** and j^1-k^1 in the plan below the bases are equal to **j-k** and j^1-k^1 in the plan. From 0 to dot **r** and so on, to from 0 to r^1, in regular order, are the hypothenuses of the tangential triangles. From 0 to the end of base, **q**, and so on, up, to from 0 to q^1, in regular order, constitute the hypothenuses of the radial triangles. The bases of each set of triangles (all of a kind) are equal, but no two of the hypothenuses shown are equal.

The length of base of each triangle and its location must be determined in order to find the hypothenuses; of course these could be figured mathematically but graphic lengths, full size, are best for pattern work. The triangles used in the pattern are all taken as having horizontal bases and thus have one right angle; the base of some of them are therefore wholly below the pitch line, when considered in position. If the bases followed the radial pitches of the roof some of the triangles would be acute and some obtuse, at the heel. The bases and their positions, as diagrammed for the purpose of indicating the hypothenuse length are determined from the plan and elevation of Fig. 390 as follows. Project downward, perpendicular to **j-n**, lines from **j**, $\mathbf{j}^1$, 3, 4, and so on to 12 and **n**, cutting the pitch line as shown. From the points where the pitch line is thus cut, strike horizontal lines to the right and others perpendicular to the pitch line, above it; on these last lines are set off the chords of corresponding lines in the plan view,—that is, the distances from $\mathbf{j}^1$, 3, 4, etc., measured to **j-n** perpendicularly—as a long dotted line same as 5-**k** and 9-**m**; these distances, indicated by heavy dots on the oblique lines are then marked $\mathbf{j}^2$, 3^2, 4^2, and so on to 12^2. To avoid confusion the sketches shown are not lettered in full. The pitch oval is drawn in free-hand by connecting points 2, $\mathbf{j}^2$, 3^2, etc., as shown. The chord distances of arcs 2 to $\mathbf{j}^2$, $\mathbf{j}^2$ to 3^2, etc., become, in regular order, the distances separating the hypothenuse lengths at the base end, when developing the pattern, as shown by 2-$\mathbf{j}^2$, $\mathbf{j}^2$-3^2, etc., along the base line of pattern in Fig. 391. The horizontal lines struck from the pitch ordinate points are lettered and numbered, to correspond with their origin, as **j**, $\mathbf{j}^1$, 3, 4, etc., to **n** along line **p-m**. It is upon these that the triangle bases are set off, letting the heel of each triangle begin on line **p-m** which cuts through 0,—the most convenient point for the apex of all. **n-S** extended cuts all the bases at the proper point and marks the base end of the hypothenuse of each radial triangle,—these are indicated, clapboard style, in solid line, the apex of each being 0, which also answers in the same way for the secondary set, while **n-S** extended measures the base of the radials, there is no such point in position to measure the base of the other triangles, so $\mathbf{j}^1$-**k** (or any other tangential line of the plan) length is set off on **p-q** extended and marked by dot **r**; from **r** a line is erected, parallel to **p-m**; then, with bases 3, 4, 5, etc., extended, the intersections become the base end of the hypothenuses of the secondary set of triangles indicated by dots **r** to $\mathbf{r}^1$. The parts so far described, as before stated, may be developed in other positions but the principles and the essentials must be embodied. In the diagram, the lines are compactly arranged in a good position to easily familiarize a reader with the principles, relation, source and step by step of derivation of each part,—the layout has also the merit of occupying little space on the sheet,—often a point of moment when laying out patterns.

Assuming that all the work shown in Fig. 390 has been done, it remains to develop the pattern, shown in Fig. 391. To do this, distances **k**-**k**^{1}, **k**^{1}-3^1, of the plan, 2-**j**^{2}, **j**^{2}-**j**^{3}, etc., of the pitch oval, and the hypothenuses of both sets of triangles; all of Fig. 390, are used in the following order, as indicated in Fig. 391. First produce line **j**-**k** at random and set off on it, hypothenuse **q**-0,—this is the slant height (at seam edge) on the low side, shown by **j**-**k** in the plan, 1-2 in the elevation, and is **q**-0 length in the hypothenuse series. The hypothenuses of the two sets of triangles and separation distances, series **k**-**k**^{1} and 2-**j**^{2}, are used alternately. The next step therefore is to set off on the pattern from **k**, the hypothenuse **j**^{1}-**k**, finding its length in the triangle series as **r**-0, and separating the base ends of **j**-**k** and **j**^{1}-**k**, pattern, equal to 2-**j**^{2}, elevation. The second radial hypothenuse **j**^{1}-**k**^{1}, plan, and dot length on **j**^{1} to 0, triangle series, is next set off from point **j**^{2} pattern, (the base end of **j**^{1}-**k**), separating it at the upper end from the upper end of **j**-**k** a distance equal to **k**-**k**^{1}, or any other space of circle **k**-**m**. **k**^{1}-3 set off from point **k**^{1}, pattern, follows next, separated at the base end from **j**^{2}, equal to distance **j**^{2}-3^2, elevation, and so on, until half of the pattern has been developed, finishing with **n**-**m**, plan, of **q**^{1}-0 length in the triangle series. The separation of hypothenuse extremities at the upper edge of the pattern is the same throughout, because the divisions of **k**-**m** circle in the plan are uniform. The separation at the base of the pattern varies because the plan circumference of the base, arc **j**-**n**, has necessarily been transformed into an oval, of which the corresponding divisions vary in length, as shown. The hypothenuses vary in length to accord with the pitch of the roof, and their length is also affected by the angle at which they are assumed or shown to stand. The rise of the roof from point to point, in the base, varies with the difference in the altitude of the triangles, graphically shown by the varying distances between **j** and **j**^{1}, **j**^{1} and 3, 3 and 4, etc., triangle series. One may have little idea of a pattern shape before development, but previous knowledge is not necessary,—just set off the lengths and establish the location of their terminal points as directed and let the pattern boundary trend whither it will. When the points are located sketch in the pattern outline, free-hand. In the half pattern shown each hypothenuse is labeled to accord with its plan line as shown. The author generally does this, if a pattern is intricate, because the mind may lose track of points when working steadily on the job, to say nothing of interruptions that may and do occur. The whole flashing can be scribed from a half pattern; if the whole pattern is desired, the second half can be obtained from the half developed. The whole pattern is shown in Fig. 391 with seam edge and flanges indicated.

Fig. 392 is a sketch in perspective, of a pasteboard model cut and

formed up of the pattern shown in Fig. 391, with the lines on. The base slant is for a $\frac{1}{3}$-pitch roof.

Cutting a flashing of uniform flare involves the same principles set forth in the foregoing, but may be done in two ways with much the

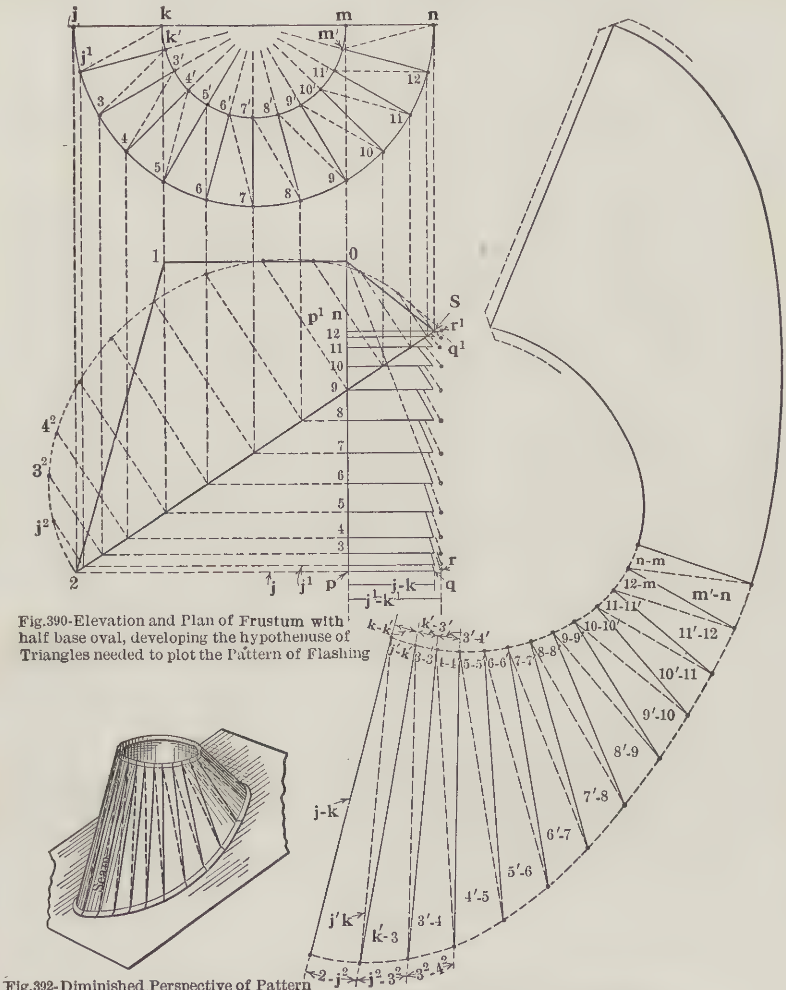


Fig.390-Elevation and Plan of Frustum with half base oval, developing the hypothenuse of Triangles needed to plot the Pattern of Flashing

Fig.392-Diminished Perspective of Pattern Formed up into Shape–⅓-Pitch Roof

Fig.391-Full Pattern of Frustum with ½ Developed from Fig.390 and every line designated

FIGS. 390–392. DEVELOPING A FLASHING PATTERN OF VARIABLE FLARE

same result,—after the plan and elevation work shown in Fig. 393 are drawn. With uniform flare the top and base circles are more or less eccentric, according to the pitch of the roof. On this account, the bases of both sets of triangles vary, one from the other, as shown by the radial and tangential lines representing them in plan, and the graduated series of bases struck from the low side elevation slant **A-x**^{1}, Fig.

393. A study of Fig. 390 will enable anyone to understand the plan and elevation work of Fig. 393 without more description than is necessary to cover unlike features. The annular space between eccentric circles changes width at a uniform rate, so the bases of the radial triangles, if set off from a common altitude line, in regular order, according with pattern methods, will all end in a slant line drawn from the widest to the narrowest base. **A**-x^1 of the elevation is already the unmeasured hypothenuse of the radials, so, producing lines down to and out from the pitch, from x^1, x^2, x^3, etc., cuts **A**-x^1 into the radial hypothenuse lengths. By measuring, it will be found that the tangential bases are so nearly a uniform increase over the radial base lengths, on the diagram, that

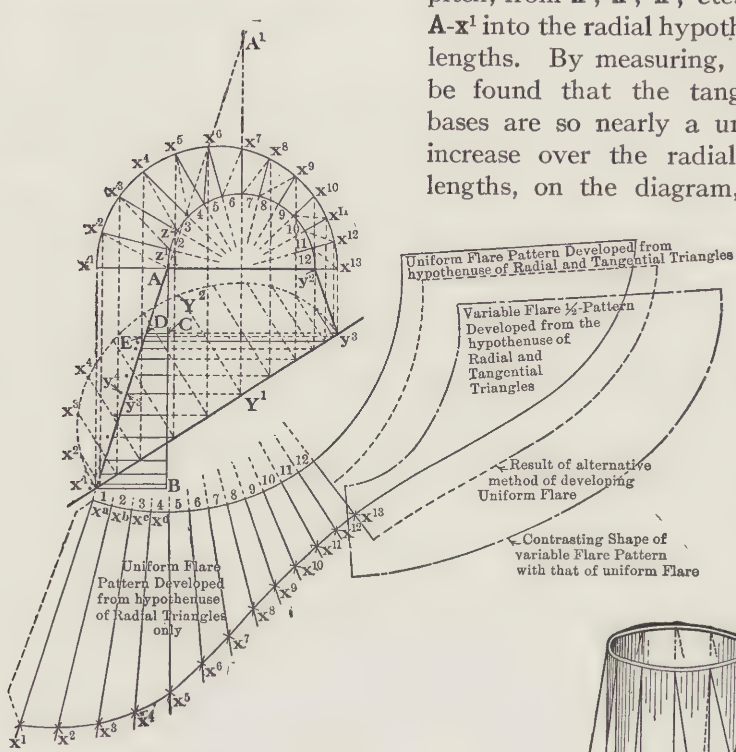


FIG. 393. FLASHING PATTERNS FOR ⅛-PITCH ROOF

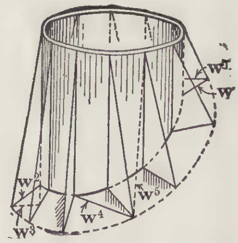


FIG. 394 PERSPECTIVE OF THE SERIES OF TRIANGLES INDICATED IN PLAN VIEW IN FIG. 393

the shortest or longest base difference as, **D** to **E**, may be set off and a line drawn from it parallel to **A**-x^1 and the lines struck from the pitch will then measure the hypothenuse length of both sets of triangles, if produced to cut both lines. The bases serve no purpose in the triangle series, beyond marking the hypothenuse lengths. Y^1-Y^2 ordinate of the oval corresponds to the center line **Y-7** of top in plan, and 7-x7 radial, of plan. **A**-y^2-y^3 and x^1 **AB** and **CDA**, tri-

angle series, the longest and shortest triangles. The pattern, not shown in detail, is developed just as was Fig. 391.

Another, and quick way to get a fair result for a pattern for a uniform flare flashing is to use the radial triangles only. Extend the elevation on the short side to a base parallel with the top and cutting $\mathbf{x}^1$, just as though the elevation for a deck flange for a flat surface was to be drawn. The slant sides and center line are then produced to intersection, as at $\mathbf{A}^1$. Distance $\mathbf{A}^1$-$\mathbf{A}$, may then be used to strike the arc for the curve of the top of the flashing, setting the compasses at **A** for a scribing center. The spaces of top semicircle $\mathbf{A}$-$\mathbf{y}^2$, plan, numbered 1, 2, 3, etc., and equal in length to $\mathbf{A}$-$\mathbf{z}^1$, or $\mathbf{z}^1$-$\mathbf{z}^2$, etc., are stepped off and the divisions marked on the arc so struck. Then, with **A** as a radiating point, produce lines of random length from the arc divisions. Hypothenuse $\mathbf{A}$-$\mathbf{x}^1$ is then set off on the first radial line as $\mathbf{x}^a$-$\mathbf{x}^1$; the next shorter hypothenuse, corresponding to $\mathbf{z}^1$-$\mathbf{x}^2$, plan, is set off on the second radial line as $\mathbf{x}^b$-$\mathbf{x}^2$, and so on, through the whole series. An equal number of spaces on the pattern arc similar to those on the top circle measures the circumference of the top, and a line connecting points $\mathbf{x}^1$, $\mathbf{x}^2$, $\mathbf{x}^3$, etc., set off as described at the base of the pattern, shapes and measures the base of the flashing for a half pattern,—the second half is shown in blank.

Superimposed over the blank half of pattern in Fig. 393 are two other half patterns in blank. The shape in dash line is that developed by the use of the hypothenuse of both sets of triangles. The one shown by dash and dot line is the same as shown developed in Fig. 391, while Fig. 393 pattern, last described employes, as before described, the hypothenuses of the radial triangles only.

This gives a good idea of the result of the three methods used on the same pitch, one for $\frac{1}{3}$-pitch variable flare, and the other for $\frac{1}{3}$-pitch, uniform flare, developed by different methods.

In Fig. 394 a series of triangles are shown in perspective, standing around a pipe in a way to make clear the functions of the triangles used in laying out the foregoing patterns. $\mathbf{W}^4$ is the base of one of the tangential triangles; $\mathbf{W}^5$ is the hypothenuse of a tangential triangle; the base, altitude and hypothenuse of the radial triangles are shown in solid lines; $\mathbf{W}^1$ shows how diagramming limits the altitude, on the short side, and $\mathbf{W}^3$ how it increases the vertical height in changing the roof slant bases,—obtuse in one place (**W**) and acute in another ($\mathbf{W}^2$) so that all the triangles as used, have one right angle. The hypothenuse length of a pattern, from point to point, cannot be altered but the work is greatly simplified by changing the angles of the base and the altitude of the triangles as shown and stated.

CHAPTER LXXV

Vent Extensions and Flashings

Aside from the skill required to cut and fit flashings, there is ample occasion for the exercise of good judgment in electing the style of flashing best adapted to the roof or building conditions to be worked to. Fig. 395 shows a vent extension terminating with a hub, into which a thimble is yarned and calked with lead in the regular way in all but that a flashing hood, made of lead, and the wire ends of a conductor basket were fixed in the lead space before the joint was run. In this way the basket is permanently secured in place,—if merely sprung into place it may blow out, or be lifted by roof painters and not replaced. The hood is thus most easily attached, without solder, in the least possible time, with as good result as is possible otherwise. If the flashing is of lead, the calking lead should be run moderately hot with more than ordinary care and with the flashing well soiled or paper-pasted to insure the sheet lead not being burnt in pouring. Care should be taken to have the return of the hood set some distance above the top of the hub before running the joint so the lead will calk down without tearing the hood. The edge of the hood to enter the hub should be dressed out to a neat fit in the empty hub, because the lead will not rise far behind it if left loose, and the calking will not do well. The flashing proper of Fig. 395 hugs the wall of the pipe reasonably close,—so close that the vent extensions must be poked down through it, or the flashing formed around it and soldered after the pipe, and roof are in place. To avoid possible leakage it is best to place the seam at the low side, though if the metal cuts to better advantage with the seam in the neck, (it often will when two flashings are wanted) it may be so cut. In this type of flashing, if a roof flange is used, it is well to turn up the flashing around the hole at **b** to fit the flashing base when it is set down over it. More or less space should be left at **a** to provide for settlement of the line which may take place in the supporting pier or through side-wood shrinkage under some resting point. The flashing and hood being separate pieces, expansion and settlement are both taken care of. The hood should not extend below snow height. The hood is best made of lead and may be pipe or sheet lead in one or two pieces, soldered or burned together. Flashings without taper are termed cylindrical, and may be of copper or sheet lead. The thimble shown has a bead on the end as though cut from the end of a length of pipe, or from a cracked fitting. Regulate cast thimbles (or ferrules) are sold by dealers but they may be cut from scrap pipe. The thimble prevents expansion of the vent air until it

reaches the top of the hub,—the air is thus a little warmer when it reaches the outlet. Cylindrical flashings are suitable for any pitch of roof, but are awkward to solder to the roof, in the neck, on half and 1-pitch slants.

Fig. 396 is the same as Fig. 395 in all but that the flashing proper is of uniform flare, and not well suited to pitches greater than $\frac{1}{3}$ unless given very little taper. Some play for settlement and shrinkage should be allowed, especially if the flashing is not lead.

In cutting through roof sheeting it is generally easier to bore the oval or circle something like shown in Fig. 397, placing the bit-center

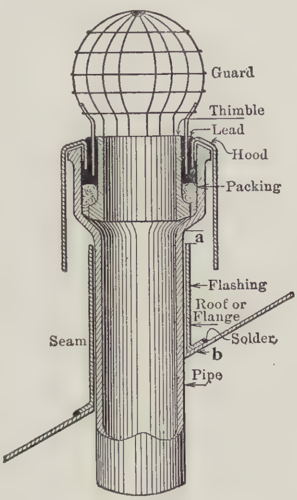


FIG. 395

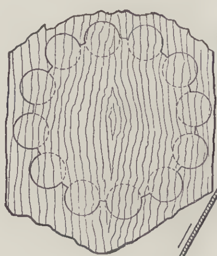


FIG. 397

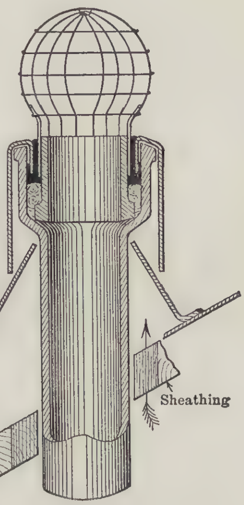


FIG. 396

FIGS. 395–397. VENT PIPE EXTENSION WORK

on the line. The solid between the holes is quickly cut and the hole can be enlarged to suit. If there is no bead on the end to be lowered through it, a snug fit that will hold the pipe steady is easily made, even in a flat roof; and, where the oval is decided, the bead will not interfere much. Of course a pipe can be wedged steady, but not so satisfactorily. A hole cut in this manner permits air to rise freely from the attic space into the flashing cavity,—an easy method of providing auxiliary ventilation, desirable in warm climates and sometimes also for warm attics in colder localities. The openings in the sheeting around the pipe provided by boring as shown in Fig. 397 are indicated in Fig. 396. The roof metal or base flange, as the case may be, is shown to extend well within the flashing base of Fig. 396. This does no harm, if left solid everywhere except at the low side. If a roof sheet or base flange is allowed to extend above where the flashing joins, unbroken, water is likely to be trapped on the low side from sweating, or from dry powdery snow finding

its way to the inside, or otherwise, to the detriment of the roof. So, roof flanges should be pierced or cut out on the low side, and a metal roof should also be pierced under flashing near the flashing flange. The sheeting, too, should in all cases be pierced,—gimlet or nail holes will answer.

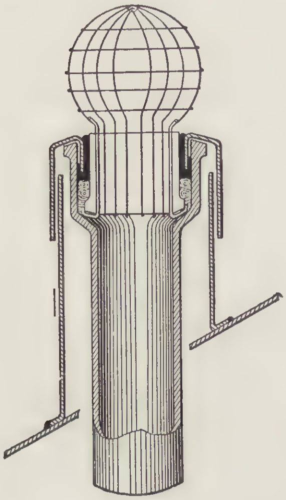


FIG. 398

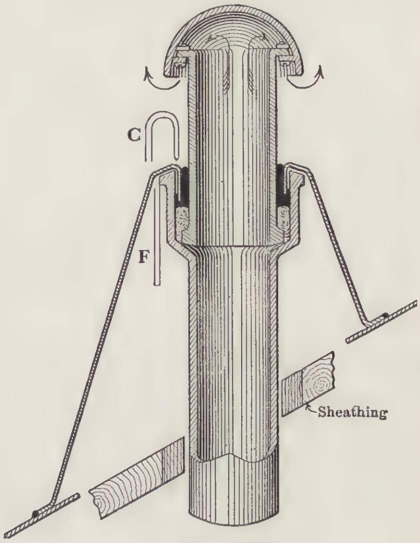


FIG. 399

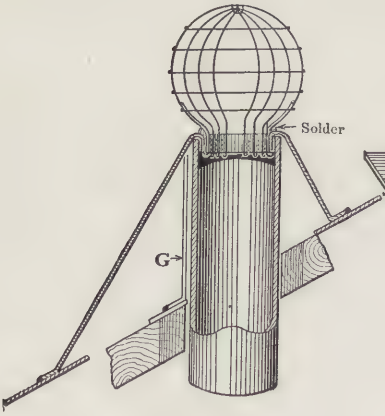


FIG. 400

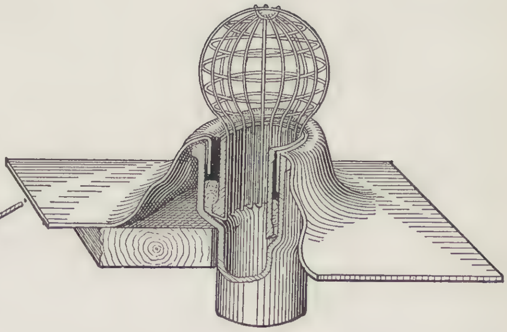


FIG. 401

FIGS. 398-401. VENT PIPE EXTENSION WORK

Fig. 398 is a cylindrical flashing of the same type as shown in Fig. 395, but made large enough to slip over the hub. It is frequently used on $\frac{1}{2}$-pitch roofs, being easier to solder than the tight flashing, shown in Fig. 395. The clearance for settlement is made between the top of flashing and the top of hood instead of under the hub as in Figs. 395 and

396. The wire basket is passed through the ferrule and the ends bent up around the lower end as shown instead of being imbedded in the lead as before described. Auxiliary ventilation is easily provided for in this flashing, if desired.

Fig. 399 is a tapering flashing connecting the roof with the hub joint direct, with a cast vent cap provided in place of the usual wire basket. The cap retards the vent current somewhat but it directs the current downward, whereby expansion of the vent air takes place below the level of the vent exit instead of above it. In still air, this without doubt tends, with some effect, to retard the formation of frost in the vent through the latent heat of the vent air vapor being liberated in a favorable position. Attic air cannot find exit to the open through this flashing, but if openings through the sheeting are provided a slow movement up and down will take place in cold weather through light warmer air from the attic rising and giving up its heat through the flashing surface. If settlement of the line takes place the angles of the return into the hub will generally give enough to let the pipe down without injuring the flashing. The return should be fitted a little high over the hub. Wrinkles are sometimes bossed into the flashing walls but they are generally too stiff to give before the return meets the call of settlement of the line, though in cases where the line is supported by a pier of sufficient bearing to prevent the line from settling as fast as the house does these wrinkles may save the flashing from being torn asunder. It is difficult to proportion the area of a pier for a pipe line with a view to matching the settlement of the house. In ordinary cases, the house support is more than ample and it is not only generally better practice, but invariably cheaper to hang the line to the house or foot it on a house pier. Cylindrical flashing, as indicated at **F**, with hood, **C**, is quite as appropriate for Fig. 399 conditions as for any other.

Fig. 400 is an example of vent extension finishing above the roof without a hub. It makes a good job if well done. Not having the sleeve nor lead joint by which to secure the wire guard, other means must be resorted to. The flashing is of the same type as shown in Fig. 399 and is much easier turned into a plain end than when a hub and sleeve must be crossed, as the latter requires considerable working if done in the solid, or goring, and burning, sweating or copper-bitting the seams, after forming, if some of the metal is removed. In the sketch, the basket wires are shown cut short and bent upward and outward so as to hook under the inner return edge of the flashing. By thus springing the basket in and lowering until the wires will come up behind the lead, then pulling up and soldering it to the flashing, the basket is secure from ever blowing out. Cylindrical flashing can be installed in the same way as dotted on at **G**. There is some objection to this plan of

flashing in cold latitudes; line settlement may carry the vent end away from the return of the flashing. This causes no leakage, but in cold weather when the house is well closed the call for air at other exits is frequently so strong as to pull vent air down into the flashing cavity,—thence though any opening through the sheeting, and so on, possibly through living rooms to some vent register.

Fig. 401 is a combined flashing and roof flange on the same principle as Figs. 399 and 400. When well done it makes an admirable job, but, on account of the work and difficulty of bossing and dummying a sheet up to snow depth, it is employed only in warm climates or over hot roofs where the hub may stand at the minimum height. While this type of flashing is oftenest used on rather flat roofs, it can be used on moderately steep pitches by making the flange a little larger and dummying the boss eccentric to the hole cut for the vent hub, in a way to raise the low side so the return will be level when the flange is held at pitch incline; the combined flange and flashing can so be fitted to a vent over a $\frac{1}{3}$-pitch roof with but little extra trouble. The basket is inserted in Fig. 401 as shown and described with Fig. 398.

A cylindrical flashing turning down into a hub is shown in Fig. 402, and the roof lines show about how the flange and shingles appear when the flashing is put in place on a shingle roof as the roofing is being put on. The courses of shingles were laid regularly up to and including the course over which the roof flange turns down at the butts. The cylinder with flange attached was then dropped over the vent and the shingling continued, leaving the flange exposed by omitting a portion of two courses, as shown; that is, the first course in the gap was entirely omitted; the second course was cut out and shortened as required and the tails of the shingles tacked in at their normal position, putting the brads above the butts of the next higher course at above the top edge of the roof flange indicated by dotted line. The roof flange extends under the shingles at the sides of the vent as shown by the dotted lines extended from the exposed side edges. The nailing of the first full course above the vent comes well up under the second course and above the line to which the roof flange needs to be extended. Nailing in the concealed edges of the flange except at the top is not really ever necessary and may be a detriment, especially if the flashing faces the southern sun. To keep the lower edge down and straight, the author bends the edge down over the butts and drives three or four 4-penny brads through the flange, endwise into the shingles as shown. The shingles upon which the flange is laid should be cut to make a fairly good fit around the pipe, and the nails in them should have the heads driven below the shingle surface. Cylindrical flashings are best for shingle and slate roofs as the flange need not be so big. In flashing a slate roof the same plan is followed as that shown in Fig. 402.

A method for flashing a vent pipe over a shingled roof already on, without disturbing the original covering, is shown in Fig. 403. The lower piece of the flange is first put in place. Half of the pipe oval is cut out in the center of the width at the proper distance from the bottom edge, and the full diameter cut out from the minor axis to the upper edge so the piece will pass up beyond the center of the pipe (pipe not shown but here supposed to be in place). The bottom edge of the lower piece is treated as mentioned with Fig. 402. The whole surface may be worked down to conform with the shingle courses covered, if desired,

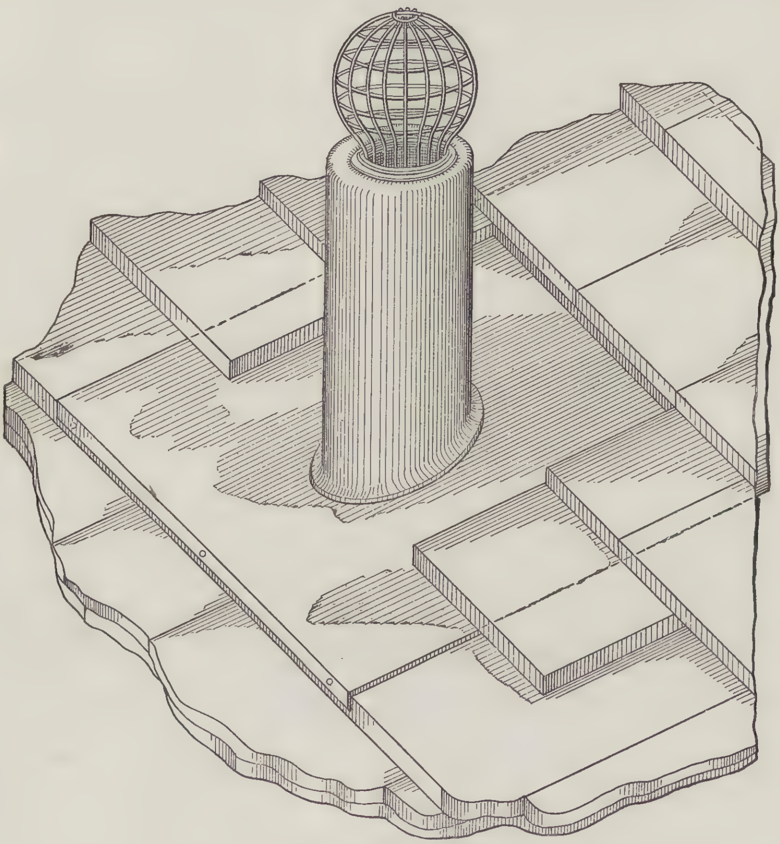


FIG. 402. ROOF AND FLASHING PUT ON TOGETHER

but the author prefers to roughly put the *roof* surface in a plane by filling the jogs made by the courses with shingle tip wedges (**aa**) bradded down. Shingle butts will make the wedges, without trimming, but they hold the flange up above the butts of the course over which it turns down and a deeper edge must be turned at the bottom. At the sides, the flange can extend a little over the filling **a**, and be dressed down, more or less, to suit the workman, as indicated by the sectional sketch in set

near the bottom of Fig. 403. The upper piece of the flange should be a little wider than the lower, and be dressed over on the side edges from where it reaches the filling on down to the lower edge. The bottom edge of the upper piece should be solder-tacked to the lower piece at several points, if not soldered to it all along. The upper piece of the flange must be long enough, from the extreme of its portion of the pipe oval, to reach up to the height indicated by the dotted line in the sketch; that is, exposed until it reaches the first line of butts (at least one full course above the pipe), then under one full course, and on to well up under the butts of the second course over the concealed part, stopping not far below the line of nailing of the first course which it passes under. The oval in the upper piece is cut out to straddle the pipe the same as mentioned for the lower piece. Before attempting to put the upper piece in place, a thin-wide-blade flooring chisel should be tapped up under the course where the flange will begin to pass under and the shingles prized up enough to let the flange slip under as far as necessary. All the prizing should not be done by lifting on the chisel handle,—place a fulcrum under the chisel, close up, and press down slowly on the handle so as to throw the whole width of the blade up against the shingles at a more advantageous point and thus lift, without splitting them. When there is room enough for a strip of lead to slip under far enough at all points, bend the upper end of the flange piece upward, leaving less than the exposed distance from the oval to the bend; slip the end under the shingles with the oval gap straddling the pipe and then work the piece down flat on the course as far as it will have to slip under; next drift it up under the shingles, and finally flatten and dress down the whole piece with the oval fitting close around the pipe and solder it to the lower piece. Drive the shingles down on the flashing with a block laid over the course to hammer on. If thought necessary nail them in the second course above the flashing. Nail through tapering strips of copper, pointing the wide end down the roof, near the upper end of the strips, then turn the strips back over the nails and work the wide ends well up under the shingle course and flatten the double down so it hugs the shingle closely.

A flaring flashing of some type is better than cylindrical flashing where the work is thus done after the shingling is finished, as in piping old buildings,—the base of tapering flashing will stand out on solid metal where it is easier to solder, and can be made to cover the oval gap, leaving the sides of the gap under cover and providing a nailing surface under cover around the pipe to tack the flange to the sheathing to make it more rigid.

Fig. 404 shows an induced draft ventilator set down over a plain vent pipe end. If an attic has no connection with the rooms, such a

ventilator may be made to serve not only as the flashing but also as the vent pipe guard and, attic ventilator, for which holes must be made through the sheathing between the pipe and ventilator wall. Where there is any chance for air to be drawn in and down into the house the attic venting should not be attempted. A plain top ventilator will do, but it does not induce a draft. There are several types in the market that cause the wind to create a draft upward regardless of the direction of the wind.

Fig. 405 illustrates a wrought pipe vent extension, flashed in a way that makes an exceptionally good job. Other schemes may however be

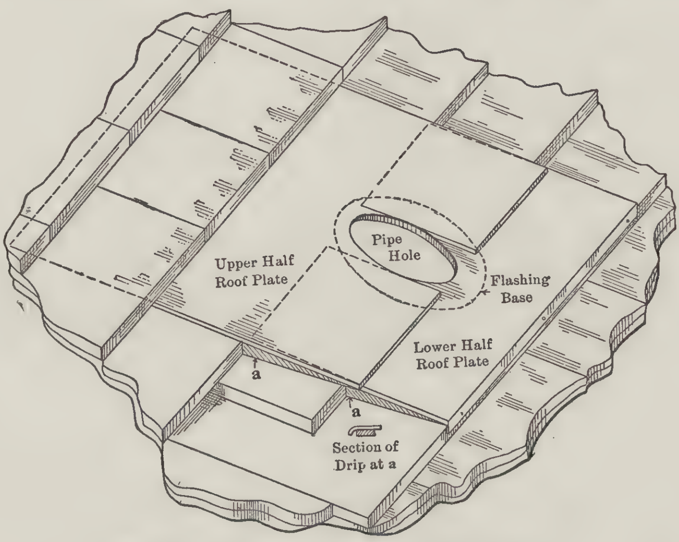


FIG. 403. FLASHING A PIPE AFTER ROOF IS ON

employed with good effect. A flashing can be fitted to return into a plain end, as shown in Fig. 400, in either cylinder or flaring style, or the flashing may be fitted close at the top and a recessed coupling screwed over the pipe so the recess will fit down over the top edge. Where the vent goes high above the roof to get above a nearby window a tapering flashing can be fitted snug at the top edge and a second, short, frustum soldered around the pipe above it; then, with putty around the top of the first, the upper frustum can be pulled down tight and solder tacked to the lower part. Also, a deck flange with a cylindrical band at the top edge can be strapped to the pipe above the flashing so as to shed falling weather.

In the flashing shown, the end of the 4-in. extension is threaded and capped with a pipe coupling; as a hood for the flashing, the outside of the coupling is threaded on one end for a $4\frac{1}{2}$-in. coupling; a half or whole $4\frac{1}{2}$-in. pipe coupling screwed over the 4-in. thus hangs down over

the flashing. The vent may end at the coupling or be extended to any desired height and the end guarded at either height as suggested by the dotted line in the sketch,—viz.: bend some of the wires to spring into the coupling and the balance to pass down outside, turning up and inward the ends of the outer wires. The basket can then be pushed down until the ends of the outer wires are below the coupling; next, by pulling up and hammering the outer wires to a close offset over the top of the coupling and binding them in with a wire surrounding the basket just above the coupling (in the neck of the wire offsets) the basket will remain in place.

Cylinder flashing base edge shapes are developed in the same way as stove pipe elbow patterns are laid out. From a semi-circle (**S-7-T**) scribed to a diameter (**S-T**) equal to that of the flashing, as in Fig. 406, ordinates are drawn of random length, parallel to each other, across and perpendicular to the diameter, from points (**S-S**^{1}, etc.) in the semicircle derived by stepping the semicircle into a number of equal spaces. Then strike the roof pitch line (**T-T**^{1}) across the ordinates, beginning at one extremity of the diameter, as at **T** in the sketch. Next, from where the ordinates, extended, cut the pitch line, strike, parallel to the diameter, lines of random length, as at the right in the diagram. Then, taking the chord of the arc of any space in the semicircle, as **S-S**^{1} or **11-T**, step off half the circumference of the diameter on any of the last drawn lines. At the height of the flashing from roof line to top on the high side, set off above **S-T** (the diameter extended) a line parallel to it, representing the top line of the pattern. It is on this last line that the half circumference of the diameter above mentioned is usually stepped off. Spaces 1, 2, 3, etc., to 12 along the top line of pattern aggregate half the circumference of the flashing top, so, next, erect lines from its division points, **S-S**^{1}, etc., perpendicular to it and the line struck from the pitch line. Intersections thus made determine the contour of the base of the pattern. The particular intersections falling in the contour line are determined by marking the intersection of lines similarly numbered, thus: The lines on the pattern plot are taken to be marked **S**, **S**^{1}, etc. throughout the series, as are also the division points of the semicircle from which the ordinates are struck. From each ordinate at the pitch-line a line is struck out through the pattern plot, so, by considering the ordinates bent at right angles, or by similarly marking the pattern series, it is only necessary to select two lines, one from each series, follow them to the intersection and mark it as one point in the pattern contour. Begin with **S** and **S**,—this is the seam length on the low side; then take **S**^{1} and **S**^{1}, and so on, to the end, for half the pattern. The other half of the pattern may be traced, or a half pattern will answer by reversing it, or, if desired, the whole pattern can be completed by con-

tinuing the marking of the intersections *in reverse order*, for the second half of the pattern. The half pattern base outline is dotted in on the plot. If the roof was ½-pitch, the pitch line would be as per **T-T²** in-

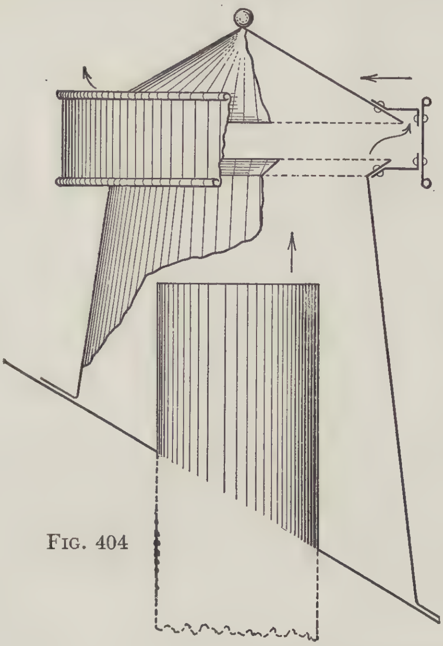


FIG. 404

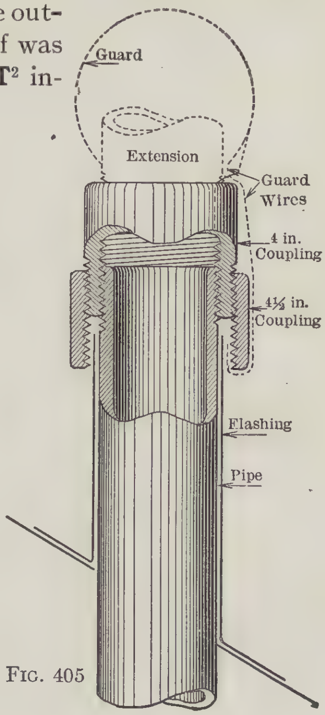


FIG. 405

FIG. 404-405. VENT EXTENSION WORK

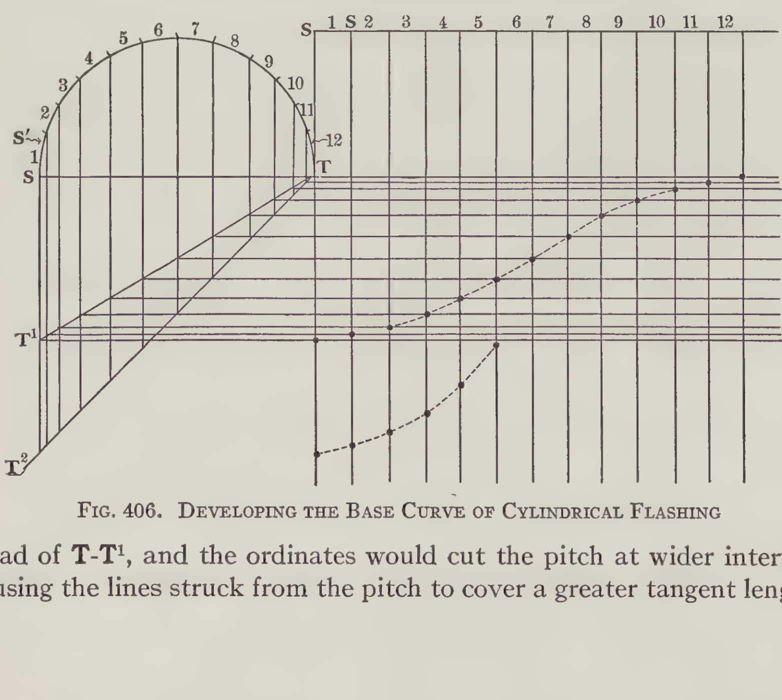


FIG. 406. DEVELOPING THE BASE CURVE OF CYLINDRICAL FLASHING

stead of **T-T¹**, and the ordinates would cut the pitch at wider intervals causing the lines struck from the pitch to cover a greater tangent length,

because there would be a greater difference between the short and long side of the flashing for $\frac{1}{2}$-pitch (**T-T**^{2}) than there is for $\frac{1}{3}$-pitch (**T-T**^{1}). The contour would then make a deeper curve at the neck as suggested by the lower dots and the seam length would be from the lower dot to **S** above it. A rectangular piece of metal equal to the circumference of the flashing in length, and to the height of the seam edge plus the height of the high side, in width, will cut two flashings without any waste,—with the seam edge of one on the long side and in the neck on the other. Any edges desired for flanges or seam must be allowed over the pattern size as above obtained.

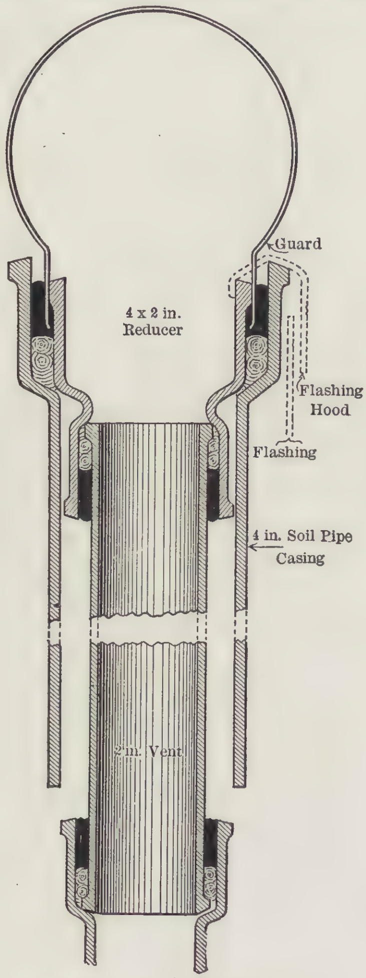


FIG. 407. VENT PROTECTED BY AIR WALL IN COLD ATTIC

Fig. 407 illustrated a method of protecting small vents, from severe weather, both above and below the roof line, the object being to counteract conditions favoring frost closure. A 4×2-in. reducer is calked to a 2-in. piece cut to bring the vent hub above the roof to the level desired when the other end sets into the hub of the line in the attic; this length gives the length for a shorter piece of 4-in. used as a frost casing; the 4-in. being cut, the 2-in. is dropped through it and the inverted spigot end of the reducer catches in the hub of the 4-in. The reducer joint space is yarned up and run at the proper stage of the work, imbedding both the hood and the guard in the joint, or the hood only, with the guard sprung inside and wires offsetted over to where they can be soldered to the lead, or with both hood and guard entering the reducer, and the hood soldered to the flashing at several points, or however will be most effective and convenient under the circumstances. The 2-in. pipe must protrude through the casing far enough to permit yarning and calking the line joint in the attic.

The sketch shows the work in section plain enough to need little description. By choking the space between the casing and the vent at

the lower end, a dead air wall is assured. If the space is left open at the bottom there will be a sluggish circulation of the air in the casing space, governed by the temperature of the attic. Protecting the pipe in this way keeps the vent air warmer in cold weather than it would otherwise be when it reached the inverted reducer level.

The reducer so used increases the area of the 2-in. vent to that of 4-in. diameter and the reduction of temperature due to expansion of the column takes place so high that a better result is obtained than when a line is increased in diameter lower down where the vent air temperature is lowered both by expansion and by increased radiating pipe surface.

CHAPTER LXXVI

Down Spouts and Laterals

Regarding the proportioning of roof leaders: A subject so indefinite as the proper ratio of leader to roof area leaves chance to disagree with somebody no matter how one may regard the question. Size, character, and pitch of roofs and the locality of the building—however little they may seem to affect the solution—will always be of sufficient importance to place good judgment, backed by experience, at the top of the list of factors governing the determination of leader pipe sizes. General statistics aid in framing general rules, but a local acquaintance is necessary before any hair-splitting begins.

The annual rainfall of the U. S. varies from 0 to 200-in. The heavy rate of fall for one neighborhood varies greatly,—due probably to hill-deflection, chilling air over and along streams, swamps or timber, or to some other not wholly understood cause, almost invariably bringing the margin of showers in a particular locality over certain spots. In some sections a heavy fall of damp snow may be followed by a warm rain, thus adding a load of melted snow to the rate of rainfall to be taken care of; in others snow is never a factor in the problem of roof water carriage, while in the belts of warm to hot summers, with cold to temperate winters, reduction of spout areas takes place in winter by interior coatings of ice. By successive freezing in exposed or semi-exposed leaders this reduction may be serious and must be taken into account either by guarding against freezing or by providing extra leader area for the purpose. Inside leaders are nowhere universal and it is only where the severity of the average winter has taught the value, that the practice prevails to a degree that would seem marked to artisans of more temperate latitudes. These are some of the conditions that cut a figure in proportioning leader pipes. Another muddling factor is the wide variation in rate of fall. Veritable down-pours ranging from 5 to 8 in. depth per hour, lasting less than forty minutes have fallen. Occasional rains, generally not exceeding 30 minutes have fallen at rates of 3 to 5 in. per hour. The bulk of moderately heavy rains last from 30 minutes to one hour. At least one-third of them exceed the 2-in. rate, though more than half those exceeding 2-in. fall short of the $2\frac{1}{2}$-in. rate. The majority of the balance are of about one hour duration with rates ranging from $1\frac{1}{3}$ to 2-in. depth per hour, with the heavier rates predominating.

The 2-in. rate exceeding an hour's duration is rare,—the rate always decreases as the period of fall increases. The greater number of 2-hour rains fall at the rate of about 1-in. per hour.

It seems from all this that but one definite rule for figuring down-spouts can be relied on,—that is "take care of the maximum fall." In practice, many figure the size of down-spouts to accord with the rate of rainfall they are willing to, or that must be taken care of, and take chances on the excess overflowing without danger.

There is no percentage of pervious area to contend with on roof work beyond the soakage of a shingle roof. Any shower worth considering outlasts *the time of concentration*—an element that must be reckoned with in proportioning street laterals. Large leaders offer less friction; the inlet is often more favorable and there is apt to be less bends for lodgment or friction. Boiler houses, gas retort houses, furniture factories and kindred buildings generally keep their roofs free of snow. A roof surrounded by fire walls with no provision for overflow may leak under the flashing or break down under the load, if leaders are not large enough. Rather flat standing seam roofs with long runs to leaders may "drown" the seams during a heavy fall regardless of the spout area; this may make it advisable to split up the total leader area into smaller units than appears necessary and thus lead to proportional increase of area in the way of extra margin allowed for small spouts.

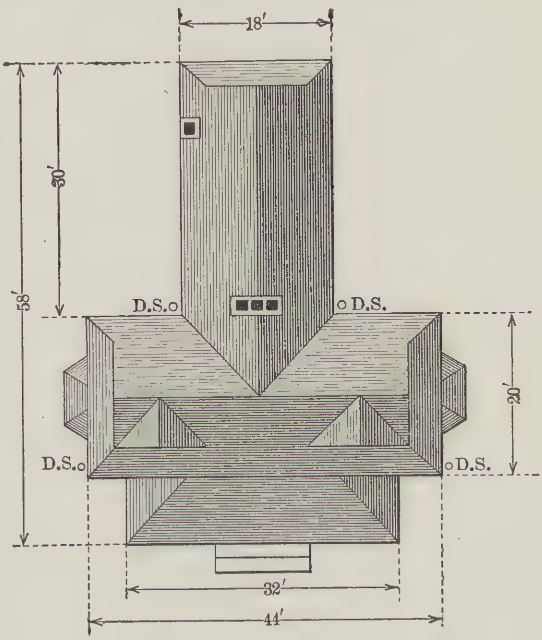


FIG. 410. ROOF DRAINAGE

For ordinary residence work, houses of 10 squares more or less, where the carriage is well divided, it is wise to place no leader less than 3-in. diameter or 2×3 rectangular, not even for a facet of one square or less, unless for a portico where the smallest possible tube that would answer might still be conspicuous.

Leaders should be trapped in the lateral connection, for if storm water and sanitary sewage go into one system the air passing up untrapped leaders unfits them to lead water that may be turned into the cistern; if the storm water is separately piped, the current of damp air

passing up the leader when not trapped will rust them out to an extent worth providing against.

In figuring leader allowance per "square" the author ignores the pitch of the roof. A roo^f may be any pitch but the rate of rainfall is per square foot of horizontal plane. To illustrate: the square foot in plan view of Fig. 410 would be used to find the quantity of rain falling on the roof,—it would be the same for any pitch, though varying per square foot of roof plane for different pitches; likewise, the spout area would be based on the size of the horizontal plane and never on the actual square foot of roof surface.

The method of arriving at the size of a spout is as follows: If 1-ft. of rain fell in 1-hr. the quantity would, for 1 square, be 100 cu. ft. or 750 gals. Eight inches per hour may be taken as the maximum that

Table XXXI. Carrying Capacity of Round Clay Pipe

Diameter pipe, inches	Gallons delivered per hour when pipe is flowing full and the grade in 100 ft. is:—					
	1-ft.	2-ft.	3-ft.	4-ft.	5-ft.	10 ft.
4	4,320	5,940	7,290	8,640	9,450	13,555
6	12,555	18,900	22,410	26,731	29,970	42,390
8	29,970	42,120	51,840	59,670	68,460	94,500
10	55,620	78,570	96,120	110,970	124,200	175,770
12	91,800	130,140	159,300	183,600	205,740	287,060
15	170,100	240,300	294,570	339,930	380,160	538,110
18	280,260	396,090	480,190	559,710	626,940	887,220
20	372,600	514,520	648,000	747,900	834,300	1,163,160

will ever have to be cared for on any building; 8-in. depth equals 500 gals. per hour per 100 sq. ft. of horizontal plane.

Plain connections are made to hanging gutters, and a shallow enlarged head that will allow the water to fall into the leader rather quietly is provided for cornice gutters. The height of the leader is ignored entirely and no allowance made for cohesion increasing the rate of fall. The head of 1-ft. is assumed and a constant multiplier of 0.6 is used to diminish the result arising from the square root of twice the gravity accelleration, thus: Vel. per second $= \sqrt{2gh} \times 0.6$, which applied to a head of one foot equals $2 \times 32 = 64$; $\sqrt{64} = 8$; $8 \times 0.6 = 4.8$ ft. velocity per second. $4.8 \times 12 \times 1 = 57.6$ cu. in. or 898 gals. per hour per square in. of down spout area. 500 gals. per hour being the maximum fall, this shows 1 sq. in. of spout area will take care of $1\frac{4}{5}$ squares of horizontal plane at any likely rate of fall.

From the above it is easy to make practical deductions. With the minimum before mentioned, allow in warm climates, 150 sq. ft. of space per square inch area of down spout for buildings with fire walls and 200 sq. ft. per inch for isolated buildings with cornice or hanging gutters; for cold climates where ice in the leader, snow, etc., need consideration,

allow 100 sq. ft. of space per square inch down spout area for buildings hemmed by fire walls and 150 sq. ft. per inch for other buildings. Protect the leaders from leaves and trash in all cases.

The sizes of ground laterals for leader spouts may be taken from Table XXXI which gives the flow per hour at different grades for all the sizes of pipe a plumber ordinarily uses.

The author makes 30 to 50 per cent. reduction when applying the quantities, especially those for the smaller sizes, according to the kind of service,—chance of partial stoppage from grease or otherwise.

If it is desired to calculate the flow for some particular grade, the formula is:

$$\mathbf{V}=\left(\frac{41.66+\frac{1.811}{\mathbf{n}}+\frac{.00281}{\mathbf{S}}}{1+\left(41.66+\frac{.00281}{\mathbf{S}}\right)\times\frac{\mathbf{n}}{\sqrt{\mathbf{R}}}}\right)\times\sqrt{\mathbf{R\,S}}$$

in which **V** equals mean velocity in feet per second; **S**, the grade or slope of drain, $=\frac{\text{Fall}}{\text{Length}}$; **n**, a coefficient allowing for roughness of pipe surface, taken as 0.013 for round clay pipe, and **R** the hydraulic mean depth of flow in feet, which is equal to the area of cross-section of flow in square feet divided by the wetted perimeter (that portion of the circumference of the pipe covered by the flow) in linear feet. For round pipes, **R** may be taken as $\frac{1}{4}$ of the diameter, for flows filling more than half of the pipe.

CHAPTER LXXVII

Sewer-Washed Interposed Dry Closets

A servants' closet seat is often housed in over the sewer, in the yard, —a vertical 12-in. or larger pipe leading down to the sewer level and through which the house sewer passes from side to side at the bottom. If the sewer line is large enough a simple tee is used to receive the drop pipe; if it is smaller than the drop, and of a size that an increaser can be gotten for, an increaser is used in a common tee to take in the drop pipe. If the sewer is 5 or 6-in. a 12×5 or 6-in. cross may be used by sinking the cross so the branches will come right for the sewer and filling the spigot part up to near the branch level and banking the cement on the sides so as to leave a nice regular curved slightly dipping channel through the bore of the cross. The soil from the dry seat above then drops into the channel where it is washed along with the sewage passing through the house line. It is the practice of some to let the bore of the drop pipe extend some inches below the bottom of the house sewer, thus giving a deep bed of water all over the 12-in. for the soil to fall into.

Whole rows of cottages without interior plumbing have been fitted with dry closets in practically the above fashion, where water and sewer were available. The usual plan is to bring a line of 10 or 12-in. sewer along through the line of outhouses. Either 10 or 12-in. vertical drop pipes, according to the sewer line size, are brought up within an inch or two of the bottom of the floor. The floors are laid over the drop pipes, and a 3½-in. hole bored through over the center of the drop. Common enameled *new pattern* Philadelphia hoppers with self-raising seats are then screwed to the floor much the same as for water service. These hoppers have much less fouling surface than boxed in wood seats and are permanent satisfactory fixtures, easily cleaned. The soil falls into the lateral and is washed along into the main sewer. No water bed is provided under the drops. Experience has proven that they so give no trouble from choking. The water for operating the lines is regularly derived from the hydrant cesspools. During rain storms the line gets thoroughly flushed out as the leader spouts also discharge into it.

Work of this nature is not strictly plumbing but can be done by no one else so well as by a plumber, and incident to his other work on a job he sometimes picks up quite an extensive job of the kind. One of such is illustrated in Fig. 412. At a large country boarding school there was a dry seat outhouse in addition to the limited indoor closet facilities. A rock walled channel through which the yard drainage passed, was covered with an outhouse having a double row of wood seats and risers

divided by a partition. The absorptive wood seat surface aggregated 120 sq. ft. and the rock channel below presented as much more, all of which was nothing to be compared to the resulting smouldering muck in the swag just beyond the channel. Timber has been cleared out, giving summer winds a better sweep toward the buildings, and odors in warm weather were very unpleasant.

A marsh on much lower ground 3000 ft. away offered a means of

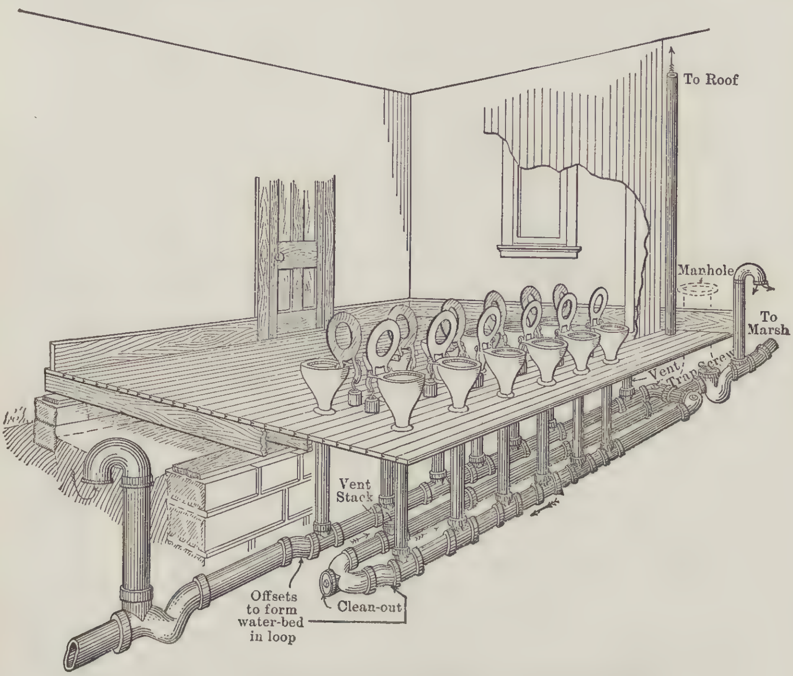


FIG. 412. DRY HOPPERS DISCHARGING INTO A HOUSE SEWER

relief and the plumber suggested piping the matter to it. This raised the question of water for flushing which could not be spared from the limited storage at hand, and the matter could not be piped without it. The plumber answered by using the drainage from the kitchens, bath and toilet rooms, etc. All waste and drainage lines were collected into one 8-in. pipe, through which a regular flow of scouring depth was obtained. A continuous 8-in. return loop practically level, was installed in the channel, with a single water bed obtained by offsetting up and down as shown. This received and passed the discharge from the buildings. Two vent lines, approximating the area of all the hopper outlets combined, were used, at opposite ends of the loop, with the idea of inducing at least a slight down current through all the hoppers.

The narrowness of the channel left but one position for the outgo,—between the loop lines and passing under the return at the outlet end.

The loop was used in order to get a vertical drop for the hopper pipes on both sides of the partition. The clean-outs are within the channel space. The channel was closed at the ends and the pipe covered to protect the water-bed from frost.

Flanged frost-proof hopper lengths were used for the upright pipes. The hopper and pipe flanges were permanently bolted together independent of the floor and both flanges drilled, to match, for wood screws. By this, instead of screwing the hoppers directly to the floor, as usual, a flange length and hopper bolted together as one piece were let down into the manifold tee hub through a hole in the floor, the flange of the length supporting the whole. Wood screws run down through the two flanges keep the hoppers rigid.

The drop pipe joints at the tees in the manifold were made with twisted hemp soaked in raw linseed oil thickened with red lead. This sort of joint makes it easy for any utility man to remove any hopper with its length in case of stoppage and the services of a skilled mechanic from a distance is not necessary for any ordinary trouble. The manifold joints were calked lead. The channel lines are standard weight cast soil pipe. The difference between the interior diameter of the hopper outlets and that of the drop pipes allows the soil to drop free of contact from the hopper to the water-bed which prevents it from sticking at the bottom.

The fresh-air inlet at the trap at the inlet end, provides a current for the stacks in the main buildings and becomes an outlet relief pipe to admit of free flow during rain storms when down spouts are crowding line to its capacity. The trap at the outlet end seals off the long line to the marsh. *Two* traps are necessary in order to secure a down draft through the hoppers.

This arrangement reduced the fouling surface 75 per cent. and presents no absorptive surface. It is necessary to swab the interior hopper surfaces with a wet mop at least every other day in order to keep them in good condition.

Installations of this order have, to the author's knowledge, given 12 years of good service and the seats and hoppers are both still in perfect condition.

The small size of a hopper outlet is an advantage in dry service over common wood-seat holes. Children frequently poke shoes, hats, cats, etc., into the vault through large wood seat holes and have been known to fall in themselves.

CHAPTER LXXVIII

Dry Wells and Vaults

If a pit is tight-walled it must sooner or later be emptied or abandoned. Such are used only for dry closets, but the usual outhouse vault, into which the plumbing discharge is often led, is anything but tight-walled. The usual construction is to dig down 5 to 10 ft., according to the character of the soil, and then insert an open drum as a protection against "caving in" while finishing the depth and afterward. The drum is made of 1×2-in. or 3-in. slats, (sometimes common flooring) nailed to double rings made up of segments pieces (**b**) nailed together with the joints lapping as shown in Fig. 414. The cracks left between the slats (**a**) vary from $1\frac{1}{2}$-in. to 3-in.

As soon as it is put in place, the drum is loaded by carefully building in a 4-in. dry wall of brick bats, beginning on the segment at the bottom of the drum. In putting the drum together, care must be taken to nail the rings in at the proper distance apart to accommodate some certain number of dry brick courses; thus, each section fills up in a way to support the ring above, which is in turn similarly loaded, and so on to the top. The loading gives the drum enough weight to make it force its way down, through any amount of side binding, as fast as the material is removed from the bottom.

If the whole depth of a pit is in clay, both the liquid and solids remain and it is too soon full if water closet soil is discharged into it, but for dry use it will last for years, and is worth emptying as required. In some localities where pervious strata is deep or unreachable, pit after pit is made for plumbing jobs, the discharge pipe being changed, or a connection made from one pit to another.

Where there is any chance of doing so, an effort is made to reach a strata of good size gravel or gravel and coarse sand mixed. Sixteen to twenty-four feet covers the usual range of depths of dug pits though deeper borings to reach the walled part are frequent. The diameter of the dirt hole for these pits is 44, 50 or 56-in. Two drums like described 6-ft. long; one 10 ft. and one 6-ft. or two, each 10 ft. long, according to the depth, answer as protection and a walling guide. The longest drum is used first. After a windlass will work over the projecting end of a 10-ft. drum, usually at 8-ft. depth, the material is drawn up by rope.

It is seldom done, but instead of finishing with a dry wall above the level of the drums, 4-ft. of 9-in. brick and mortar wall should finish out from the top of the drum to a little above the surface, as indicated at **C** in Fig. 414, which, it will be noticed, projects 3 in. into the vault space,—

necessary because a full brick length is laid across the segment and slat, with the outer end flush with the outer side of the slat. If the 9-in. wall is built flush with the inside of drum or bat wall, as indicated at **d**, the necessary earth ledge, **d′**, is most certain to throw it in as the wood becomes doughy from age. If cement mortar is used in a 9-in. wall, projecting outward, it will sink as a monolith and crowd the bat wall inward by pressing the earth behind, or else, hang up for a time and let the bat alone sink; then drop with equally ill effect.

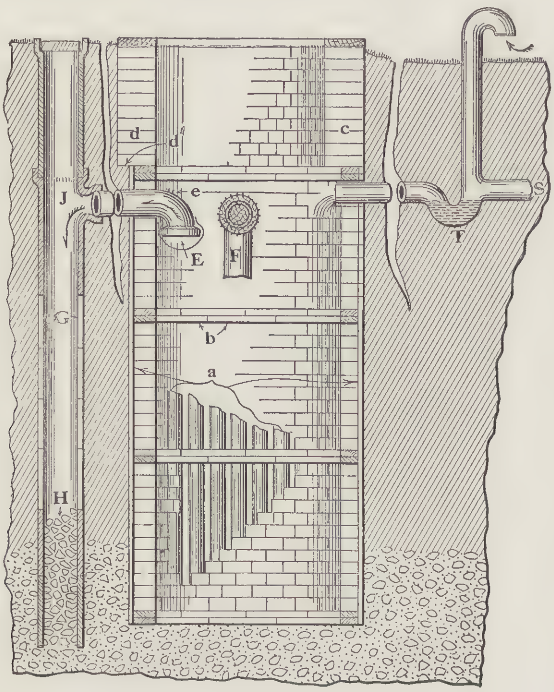


FIG. 414. DRY WELL AND PIT COMBINED

The house sewer line is shown at **S**, with trap and fresh air inlet **T**. Thus ends the sewer pipe work where the vault passes through the impervious strata. Vault bottoms get crusted over in time so the water cannot find its way out. Such crusts are often broken from above by boring through, or by perforating with a rod.

The trouble with bottom crusts may be obviated by boring down in the pit when first dug, a few feet below the bottom, and bringing up an 8-in. pipe along the wall and terminating with a mesh covered bend as shown at **F**. Then, if the bottom stops leaching, or ends in an impervious bed and the pipe reached down to sand and gravel, the water will pass down the pipe by overflow, leaving the solid matter in the vault. If provision for so removing the liquid is to be made, the best method for a new or old vault, whether the pit reaches a draining strata and thus becomes a "dry well," or not, is to bore and line at the side of the vault, a 6 or 8-in. pipe well reaching to the strata it is desired to discharge into. The pipe well is connected to the vault as shown, **J** being a sewer pipe tee, and **E** a bend,—with air hole at **e**,—covered over the hub with wire mesh to prevent paper from floating up into it. From **G** down the lining is hubless tile or sewer pipe with the hubs knocked off. From **G** up, all is common sewer pipe, but may be made of cast soil pipe.

The upper end is fitted with a tight cap or cover. The filling **H**, hard broken brick or rock, is not essential. At most, it will accumulate slime where it can be reached by digging, if filled to **J**. If the filling is omitted a rod or small auger can be used to open the bottom if it is ever necessary. The practice of filling originated in filling unlined holes to preserve the cavity.

A 20-ft. 5-ft. vault arranged like shown, with the cross connection, **J-E**, 5 ft. below the surface, will last a life time if the pipe well reaches good size gravel, though the vault of solid matter may have to be removed every ten or twelve years.

CHAPTER LXXIX

Septic Treatment and Disposal of Sewage

So much has been written about the "septic process" in presenting from time to time its complex adaptations to municipal and community service, and so little has been said about the bare essentials of simple septic treatment, that many imagine the process not intended or suitable for ordinary plumbing work. City systems, it is true, make individual treatment unnecessary for urban jobs. The lay of the ground does not always favor easy installation in isolated work, and, other handy, though questionable means are elected in many cases because of supposed cheapness, etc. A plumber's conception of what constitutes septic treatment may be rank, but, as the author understands the subject, there is nothing mysterious or difficult in the application of this ideal safe and usually cheap method of rendering soil outfall harmless. It requires no chemicals and, in common work, no special features to set up and continue the action.

To provide immunity for our particular customers alone is not the measure of our responsibility,—the residents of contiguous, even remote property, are entitled to whatever assurance of health our best efforts in sewer work will secure to them. There is, of course, in plumbing as in other lines of work, a great difference between necessity and expediency. This is the fork of the road where both owner and plumber are likely to hesitate and then elect the mere necessary, forgetting that the expedient course includes the necessary and that with *its* contingents is far better.

The household of a given premises is doubtless safe from possible direct harm from discharging the drain straightway into a creek or over the surface of an adjacent hillside. It may not be necessary, merely because no law compels, to previously treat the sewage but it is expedient to do so in order to avoid pollution of the water supply to others. Every inch of ground surface, however remote the location, is a watershed contributing more or less directly or indirectly to some water supply or other, possibly that of the immediate job. For this reason it is recommended that the septic process always be employed in isolated jobs, where possible, at least to the extent of passing the house outfall through a chamber like shown in Fig. 416 after which it will be less harmful and may, if necessary, be discharged on the surface where it will oxydize more or less completely, before being rain swept, thus minimizing the danger of contaminating any water supply.

It is the night soil that the septic arrangement is mostly designed to

handle, though some or all of the house waste may be included in what passes through the chamber, according to the size and character of the job, climate, etc. If the soil with its discharge water is considerable and the waste but little and consisting largely of hot water, it may all be piped together, especially if the climate is cold, for septic action is said to be too sluggish to worry with unless the chamber can be kept up to 55 deg. F. or more. In small jobs, including some of the waste water it is an advantage in that it dilutes the soil and thus aids in keeping the system active, and too, because the hot water brought into the chamber along with the waste helps to keep up an effective temperature through cold weather. Where there are a number of baths, lavatories, etc., it is best to take care of most of them separately, turning into the septic system the discharge of only two or three waste water fixtures that receive a liberal share of warm water.

Speaking more specifically of the nature of the subject, the septic treatment of sewage is said to be a biological rather than a chemical process, as its success is dependent upon presenting conditions which favor the rapid growth of certain bacteria. In the complete reduction of sewage, it is brought to a harmless state, largely in the form of nitrates which plant life can take up as food. Two forms of bacteria are employed—anaerobic and aerobic. Air and light are stated to retard the multiplication of the first of these and the second requires oxygen and multiplies rapidly in the open air. The anaerobic tank or chamber is a sort of catch basin, made in any convenient form favoring the requirements for the propagation of anaerobic bacteria. These, it is said, reduce the sewage to simple compounds. The tank should hold the output of about one day's use of the fixtures discharging into it. Light and air are excluded. Warmth to the degree before mentioned is essential. Such heat as is common to a pit in the earth, closed at the top, with no unnecessary exposure, together with the heat of the diluting waste water and that generated by the action taking place in the sewage itself is generally sufficient to favor the process in winter weather of severe climates.

Both the inlet and the outlet of the tank are below the surface of the contents when the tank is in full operation, so that the scum which forms on the surface of the liquid will not be disturbed by the entry or exit of matter. This scum, resembling wet ashes, helps to retain the necessary heat and further insures the exclusion of light and air from the liquid mass supposed to be already well protected from light and active air currents,—all favoring the accomplishment of the purpose. The scum may acquire from a few inches to fifteen or twenty inches in thickness, according to conditions and nature of the plant.

The matter having been altered, in the closed chamber from its initial complex nature to one of simple chemical compounds, consisting

principally of nitrites, the reduction process is completed by a change from nitrites to nitrates, brought about by exposure of the matter, in a suitable manner, to light and air which give the aerobic micro-organisms a chance to work. In large plants elaborate methods are adopted to favor the aerobic or oxydizing end of the operation, mostly through filters of special design, all aiming to secure absolute stability and harmlessness of the final discharge from the sewage disposal plant. In small jobs the oxydizing feature is not given such strict attention. Oxydizing would ultimately be accomplished by discharging directly into a stream, but a more rapid action is obtained by interposing an open or closed shallow bed of broken stone or slag for the liquid to flow through or over so as to break up and bring into contact with the air as large an amount of surface as possible before piping to a stream or otherwise.

The bacteria necessary to the first stage of the process are always present in abundance in fresh sewage, and no preliminaries are necessary to their operation. Complete treatment changes sewage to a colorless odorless liquid, described as stable and harmless.

Failure of septic action to set up or continue in the anaerobic chamber, may result from lack of warmth, or may come about through the presence of fresh air or light favoring instead a putrescent condition of the contents such as is usual to that in a common cesspool.

From ten to thirty days may be required to establish septic working conditions in a new job, depending more or less upon the season, character of matter, amount and temperature of dilution, distance the chamber is from the fixtures, material and construction of tank or season of building, with reference to the amount of heat needed to warm it up, etc.

Some patented devices are made especially for small work, looking to the placing of the tank within doors where there will never be any trouble due to lack of warmth. These are good where it is not possible to sink the chamber in earth or in some other way conserve the heat without incurring equal or greater cost for artificial protection. A sludge lift for elevating the contents of the tank to any desired level can be purchased, though it is a serious item of expense in small jobs where the lay of the ground does not favor simple gravity or syphonic outflow. Ready-made tanks and elevating apparatus are best learned about through the makers' literature.

As oxydation will eventually take place without the workman's aid it is frequently allowed to do so on small work,—sometimes by permitting the discharge to go broad cast over the brow of a knoll as shown in Fig. 416, if such is not too near the house and is otherwise favorable, and at other times by piping directly into a branch or creek. Where the outfall stops on the surface, rooting may be checked, if hogs roam at large, by littering the ground with stones.

If a stream is to take the outfall direct from the tank, it should not enter above any immediate water supply or drinking place of pastured cattle,—it would be better to stop short of the stream and let rainfall wash the matter in only partially oxydized. The discharge from the tank can be turned loose in a protected walled ditch or trench open to the air, but somewhat obstructed by broken stone or otherwise, and then picked up again and piped away to the final point of disposal. When irrigation is the means of disposal, tanks with syphoning chamber are sometimes used in order to deliver quite a body of liquid at once. With a tight delivery line and header, the liquid is thus banked in the header fast enough to insure a general feeding of the perforated or open jointed irrigating runs connected to it. "Blind" disposal has been

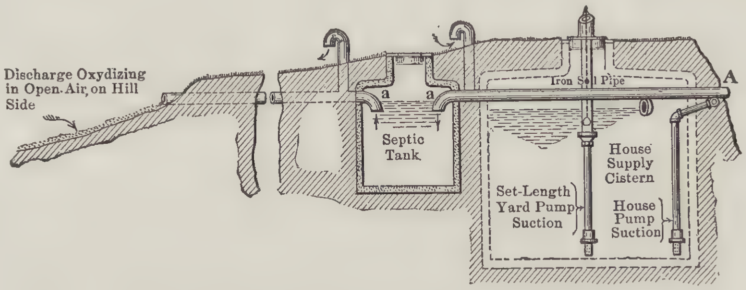


FIG. 416. FARM HOUSE PLUMBING WITH DISCHARGE FROM SEPTIC TANK OXIDIZING IN OPEN AIR ON ADJACENT HILLSIDE

resorted to in some instances. In these the outfall of the tank is piped into a buried bed of broken stone arranged for the free circulation of air to and from the surface, the rock being covered with hay or cloth to prevent the earth filling above it from drifting down into and choking the crevices. The bottom of the rock bed is connected at several points to a sand or sand and gravel strata below.

Whether the foregoing is all strictly correct or not, it covers the author's grasp of the subject and his work has for years been done accordingly and with satisfaction to all concerned.

Fig. 416 shows the tank and outside piping for a small farm house job depending upon surface discharge for final disposal and oxydation. The vent near the tank on the outfall side permits a current through the line from the discharge end. Through most of the year this aids in the oxydizing work, bringing air in contact with the flow as it passes out through the pipe, though in very severe weather it may do more harm than good by chilling the contents of the pipe. The vent on the house side permits the flow to enter the tank easily and is also the source of fresh air supply to the house system. In cold climates the fresh air current will chill the flow to the tank much less if the inlet is placed nearer the house. In the absence of these vents, vent holes should

be placed in the bends in the tank, as at **a**,—it is not a bad idea to punch them, even though the regular vents are installed.

Incidental to the septic feature shown in Fig. 416 is the example of a sewer passing close by a drinking water cistern. The tank is not so near the cistern as it shows in section. Where a waste or soil pipe runs thus close to a storage cistern, every precaution should be taken to insure no leakage from the pipe,—this means that cast soil pipe carefully joined with lead should be used, and laid carefully on undisturbed earth in turn is not likely to be disturbed by settlement around the cistern excavation. To be certain of permanent alignment the filling around the cistern wall must be well tamped,—from the bottom up, if it is being built along with the other work. If there is considerable distance between point **A** and the house, the line to the chamber need not be iron all the way,—passing the cistern and ten feet each way with iron pipe will be enough.

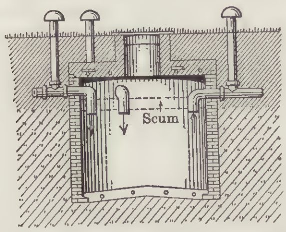


Fig. 417. Section of Anaerobic Chamber

Another tank is shown in Fig. 417. It belongs with the work shown in Figs. 418 to 420. These tanks, for ordinary jobs are all on the same principal, and may be cylindrical or rectangular, varying in size to suit the job. Forms for rectangular tanks are so much more easily made than curved forms that circular concrete tanks are seldom made. When the walls of a tank are to be brick, the arch can be turned with brick as for a water cistern.

If the depth possible is too little to allow turning a brick arch, a concrete top, as shown, can be put on. Concrete is very strong under compression strains, but so weak in tensile strength that it must be reinforced with bars or rods of iron or steel. The place for the reinforcement of a slab is near the bottom. From 4 to 7 in. thickness, according to size of tank and kind of concrete, answers for the top. Cinder concrete is not strong like that with gravel and rock and the author does not hesitate to make a large cinder top ten to fourteen inches thick, and to use old gas pipe instead of rods as reinforcement, placing the pieces at right angles, about 2 in. from the bottom one way and 3 in. the other. Four inches thickness will commonly do for concrete walls. Unless the tank is small and built in firm clay the walls should have rod reinforcement, placed about three-quarters of the thickness from the inside face. Concrete bottoms are better if provided with latticed reinforcing rods placed near the bottom. Whether bottom reinforcing is needed or not depends on the size and kind of side walls and on the character of the soil. If circular walls are of reinforced concrete and the bottom built arched up between them the bottom cannot break down without also

thusting the walls out. If the walls are of brick in firm material, and the bottom is flat or dished concrete, deflection does not add any strain to the side walls. Brick side walls should, as nearly as practicable, be

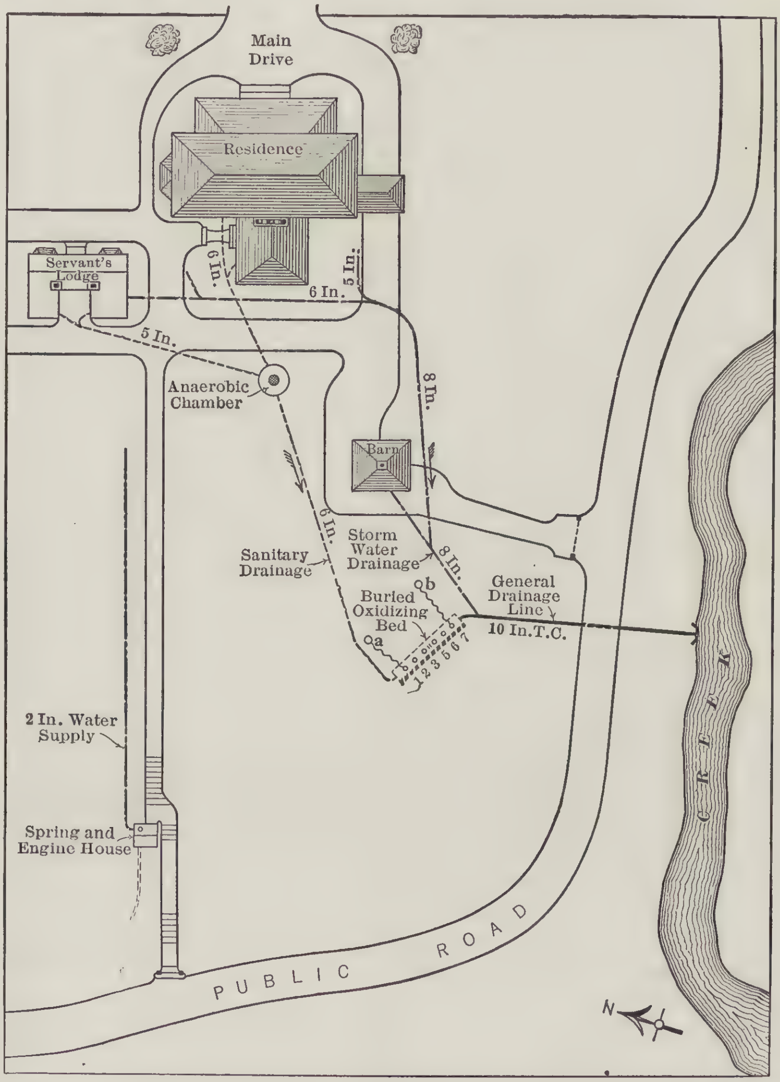


FIG. 418. SUBURBAN RESIDENCE DRAINAGE SYSTEM WITH SEPTIC ARRANGEMENT FOR THE SANITARY OUTFALL

laid against undisturbed earth and slushed up behind with mortar,—if the digging is too rough to depend upon slushing for filling behind, then dirt should be tamped in solid as the wall is built. The green wall will give a little while tamping, but the inner plastering and not the wall

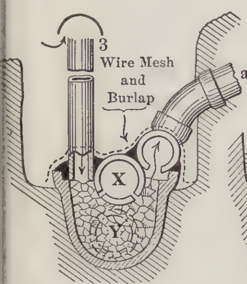
joints is what makes the walls water-tight. At least a $\frac{1}{2}$-in. of cement plaster should go on the interior of brick walls. Hand molded brick are better for cistern walls than any sort of machine brick. Unplastered hand molded brick, leak like a sieve (make good filter walls) but they "take" and hold mortar and plaster better than any other. These hints may help to produce a good tank on remote work where the plumber is likely to have to answer or attend to all questions concerning the construction of the tank.

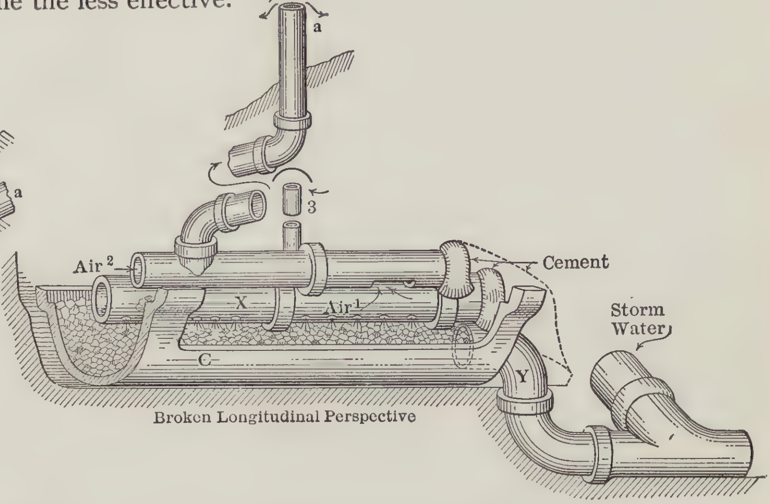
Long pattern clay $\frac{1}{4}$-bends will dip down far enough to avoid the layer of scum forming in the average tank. For large tanks iron bends extended down to 15 or 20 in. below the line level should be used. The outlet and inlet should be placed at about the same level.

Fig. 418 is the residence plot of a country place showing the storm water and sanitary drainage lines of a job in which the septic process is provided for the sanitary outfall, the final disposal of all being into a nearby creek. Dash-and-dot lines indicate roof and fountain water and the waste from the residence fixtures, except one bath room, the sinks and the slop sink. Dotted lines stand for the sanitary sewerage. The anaerobic chamber indicated in Fig. 418 is represented in section by Fig. 417. The oxydizing bed, indicated, is shown in detail by Figs. 419 and 420. It was thought it might be necessary to change the storm water line below the barn, and enter it into the sanitary sewer on the house side of the bed so the rain water would go through the oxydizing section and flush it out at intervals, but there has been no occasion to do so.

Fig. 419 is not a Gatling gun, it is merely a clumsy, broken, side view of the buried oxydizing bed. The bed wall, **C**, is of large gutter or conduit pipe, much like the split forms used inverted for covering fire-walls to prevent weather erosion of the joints. The trench formed by a dozen lengths of this kind joined end to end was filled with broken rocks as shown. The inlet line, **X**, runs along over the rock. It is closed at the outlet end and is perforated along two lines, leaving a solid stripe between the holes, on which the pipe rests. The liquid from the tank trickles out through the perforations in **X** and down through the rock. Larger pieces of rock than were used for the general filling are ranged along the bottom of the bed in a way to make a rather free passage to the outlet pipe **Y**, the mouth of which is on a level with the bottom of the bed. The end of the bed, air pipe and inlet lines are all completely closed by one general cement joint or mass at the outlet end. On one side of the inlet line, beginning at the rock, are ranged a number of 3-in. upright pipes which extend above the surface. These are represented in Figs. 419 and 420 by the figure 3, and are numbered 2, 3, 5 and 6 in Fig. 418. Air from the open for oxydizing the liquid passes down through these pipes and is intended to find its way through the rock filling around

under the inlet line and up and out through a perforated air pipe laid along the rock surface on the opposite of inlet pipe **X**. This air line over the rock has two exit pipes opening on the hill side at a higher level than the air inlets. These are numbered 1 and 7, **a** and **b**, in Fig. 418, and indicated by **a** in Figs. 419 and 420. The higher level of the exit pipe ends is depended upon to induce the current for changing air in the bed. Caps that would induce a draft could be substituted but it has not been found necessary. Doubtless much of the air passing through the bed cuts across through the delivery line perforations, but the arrangement is apparently none the less effective.





. 420. Buried Oxidizing Bed

Fig. 419. Buried Oxidizing Bed

The air exit pipes are taken from the collecting line by tees near the ends of the bed. The air comes to the exit branches from both directions, as indicated by *air*[1] and *air*[2] in Fig. 419. The bottom of the collecting line is broken out in spots at a dozen places along its length, as seen in Fig. 419, near *air*[1], so that the current may rise from the rock filling into it at many points. The air and delivery lines over the bed rock are heavily cemented together and to the bed walls. A wire mesh was laid over the whole bed from earth to earth and burlap laid upon the mesh before filling in. This is indicated by a dotted line in Fig. 420 which also gives a better idea of the pipe arrangement than would Fig. 419 alone. The rain water joins the discharge from the bed, as shown.

From what has been said the reader will find means to improvise many other layouts and simpler ones too, than the one just described.

CHAPTER LXXX

Trench Work Hints and Repose of Materials

There is much homely science in handling a pick and shovel. Experience teaches unlettered philosophy that which books cannot, for a thoughtful, experienced, light-weight man can get more dirt out of a trench in a day, with less labor, than an inexperienced or stupid man of twice his weight can in two. Personal experience is so dear a method to learn by, however, that it is hoped the reader may find profit worth his while in the following commonplace hints: Most journeymen hope to, and every apprentice expects to become a master plumber, a capacity in which he would have to select, instruct and guide labor more or less to avoid loss through indifference or incompetence. Even an apprentice should therefore study the methods of rapid trenchers, for observation will gather more good points than can be found on record.

Clay, or other material in a state to make it cloddy or lumpy when excavated may be counted upon to make about a third more in the heap that it measured in the virgin state. The angle of repose in the heap, for several materials is given on the diagrams in Fig. 422. The lower series contrasts sections of heaps with slant sides of equal length and the upper illustrates the same with equal bases. Without lugging in the tedious trigometrical functions necessary to a close comparison it may be said that a section of the heap for cloddy clay and soil (angle of repose 43 deg.) has about four times the area of one of wet earth with equal base and 14 deg. angle of repose. Sections with equal slant sides have about twice the area at 43 deg. as at 14 deg., and a heap with 14 deg. angle of repose having sectional area equal to one with 43 deg. angle has about twice the length of base.

Materials that repose at low angles must be thrown at least one-third further from the trench for equal quantities than do those reposing at the steep angles shown, though ordinarily, the labor does not vary much from those that find a steep slope and therefore require to be pitched higher. For ordinary trenching where there is room for the heap, one error often made is to begin throwing the dirt too close to the trench, soon making it necessary, at much unnecessary labor, to pitch over the heap to keep the earth from rolling in again. When the trench is to be of more than ordinary depth, the first pitching should go well out of the way so no pitching over from greater depths will be necessary. The length of time the trench will have to stay open, and whether shoring is necessary or intended are factors affecting the distance earth should be pitched to. Reasonably dry clay is firm for a few days and may be so

trusted, especially when dug in pockets and tunnel-spaded between, to depths of from 5 to 9 ft.,—if there is no traffic-jarring, frost or rain. Any of these leveling agents or heavy loading to the brink with the heap will soon overcome the tenacity of the trench-wall material. Any deep trench to go open over night should at least be secured at intervals with upright 2×6 or 2×8 pieces with braces. If the trench can be carried along by stages, opening and closing portions each day, any ordinary depths can be handled without shoring, if the heap is divided and kept well free of the brink. The diagrams shown have no particular value beyond picturing the angles at which materials repose,—shapes so contrasted, when associated with names and figures, as these are, generally make a more lasting impression on the mind than would text alone, even though it be tabulated.

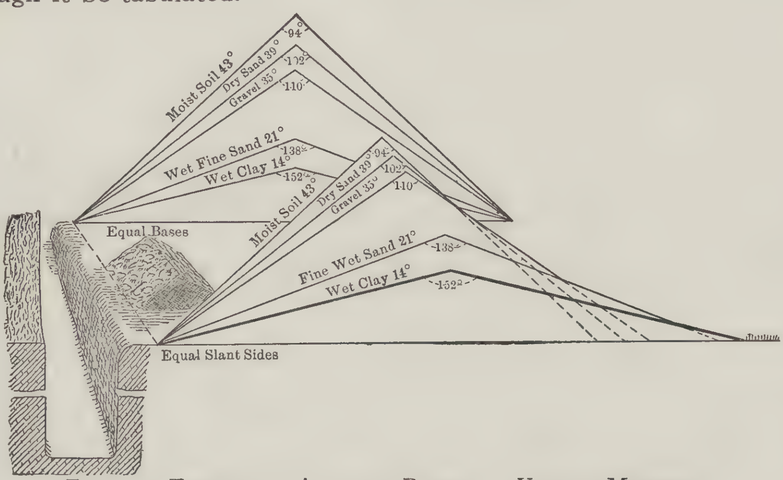


FIG. 422. TRENCHING—ANGLE OF REPOSE OF VARIOUS MATERIALS

Common supply pipe trenching offers frequent chances for losing or gaining in time according to the skill of the trencher. An unskilled man is likely to dig a short space, to the proper depth, and then stand in the hole and pick the balance down and throw it out from the bottom. This requires nearly twice the work, but the author has found more than one new man of mature age killing himself in that fashion without making much ditch. To illustrate, suppose a trench to be two feet wide and three feet deep; if the dirt is thrown out by layers of spade working depth, say 6 in., six layers would equal the trench depth; the "lift" for each layer can be taken to be from the top of the trench down to the center of depth of the layer,—for the first, $\frac{1}{4}$-ft.; second, $\frac{3}{4}$-ft.; third, $1\frac{1}{4}$-ft.; fourth $1\frac{3}{4}$-ft.; fifth, $2\frac{1}{4}$- ft.; and sixth $2\frac{3}{4}$-ft. Each linear foot of each layer ($6\times24\times12=1728$ cu. in.) would equal 1 cu. ft. If the earth be taken to weigh 118 lb. per cubic foot, then the lifting work for each linear foot of trench, to get *all* the dirt from the *bottom* would be: 118×6

=708 lbs.; 708×2.75=1947 ft. lbs.; if the dirt be pitched out, layer by layer, instead of picking down, taking the successive lifts to be as given above, then the same result is secured by: 118×0.25=29.5; 118×0.75 =88.5; 118×1.25=147.5; 118×1.75=206.5; 118×2.25=265.5, and 118×2.75=324.5 lb.,—a total of 1062 ft. lbs. labor required to lift the weight of one linear foot of trench to the top. 1062÷1947=0.54, showing the labor of lifting out, layer by layer to be about 46 per cent., less than pitching *all* from the *bottom.*

The above is only one example of the many ways a laborer can work to a disadvantage, but they are all akin. Worrying with too big a bite with pick or spade; leaning forward and spading straight down, requiring a leaning back and ratchet action of the handle to break the hold; failing to cut the sides of tenacious stuff; dumping too close, and then pitching over; ramming too little and having dirt left; ramming too hard and having to wheel dirt to fill; pitching where the heap will have to be moved to complete the work; littering and cleaning up, or protecting both sides of a lawn trench when one side will answer; not saving the sand under brick; pitching the heap on brick that have been taken up and stacked; cutting sod too thin, and not saving or not protecting it, thus having to get new sod; making the trench too roomy or not making room enough to work in; digging too deep before grading the bottom; trenching where drilling would answer; not bracing or shoring to save "cave-ins," etc., is as much a part of learning the trade as is learning any of its proper manual operations. Skill in such matters is a part of every good mechanic's ability and a thorough knowledge of the trade and its kindred work is requisite to a successful master.

CHAPTER LXXXI

Trenching, Grading and Shoring

Excavating for sewer and water-supply pipes is the commonest of manual labor but the circumstances of ordinary shop practice are so various that not more than a few general remarks, and some details of regular routine can be gotten into a limited space.

For very heavy trenching such as is mostly done with power tools and seldom within the scope of a plumber's field of operation it may be worth stating that a track shovel, like used for railroad cuts, is fit only for open stretches and can be used only for the depth the shovel will lift as shoring the trench prevents making a second trip. When a greater depth is necessary, the slope required to let the car pass makes the track shovel of doubtful value for any depth because expensive filling behind the shoring becomes necessary and the filling is never so reliable as virgin banks. It is impossible to shore up closer than the car length, plus the shovel reach, and in some work the banks cave so badly as to make dumping into vehicles very inconvenient.

Derricks with suspended cable and bucket lifts are suitable only for alleys or other quarters where tools more appropriate for general work cannot be profitably operated, unless the back filling feature for some reason offsets the usual disadvantages. Trussed carriers riding a track straddling the trench are used to advantage in back filling.

Trussed shovels riding on a track straddling the trench are the most profitable for the depth they work to, in either open or cramped quarters, so long as there is side room for the track for back carriage or vehicles. In this arrangement the whole machine travels above the level of the trench and effective shoring can be kept built up close to the shovel.

If the material handled is sand or any other that an orange-peel dredge will dig up, the crane may follow the course, backing away from the trench and dumping on the heap, in vehicles, dump cars, or back filler.

The clam-shell of ordinary construction usually does the best work either in lifting from hand-pickers in the trench, or in refilling from the heap.

In disposing of earth from a trench side, the distance it is to be carried governs whether barrows, one-horse or two-horse scrapers, vehicles or dump cars will be used. These are named in the order in which increasing distance generally suggests their use, except that small dumping cars with moveable track are often used to follow beside the trencher for back-filling.

The following costs represent a fair average for the depths and

pipe sizes given, laid without sub-drain and with labor at $1.60 per day.

These costs will vary with the season, amount of ground water to be contended with, hours considered to be a day's labor, price, tools, method, skill in superintendence, haulage or freight on pipe and lumber, etc., but they constitute a good check on what local estimates should foot up to with sensible allowance for favorable or adverse conditions.

Table XXXII. Cost of Drain Lines Laid Complete

	Depth of Trench	Diameter of Pipe, Inches							
		6	8	10	12	15	18	20	24
Cost per linear foot......	5 ft.	$0.60	$0.70	$0.80	$0.90	$1.10	$1.40	$1.60	$2.10
Cost per linear foot......	10 ft.	.90	.95	1.05	1.15	1.40	1.70	1.95	2.50
Cost per linear foot......	15 ft.	.....	1.50	1.60	1.70	1.90	2.25	2.50	3.00
Cost per linear foot......	20 ft.	.....	.....	.....	2.40	2.65	3.00	3.30	4.00
Cost per linear foot......	25 ft.	.....	.....	.....	.....	.....	4.00	3.50	5.50

For the ordinary run of plumbing shop trench work, for supplies, which run about 3-ft. deep, it is common practice to allow 7 cents per linear foot for digging and filling open trenches, and 5 cents per linear foot for digging and filling pocket-and-drilled trenches,—these prices do not cover taking up and relaying long stretches of sod or paving.

For drain trenches averaging 3 ft. to 4-ft. deep and not exceeding 7-ft. to 8-ft. deep at the deepest points, 50 cents per linear foot for the total length of trench is usually allowed. If dug in pockets and tunnelled, the aggregate pocket length exceeds that of the tunnelled portions by about $\frac{1}{3}$. In pocket and drilled trenches drilling is more quickly done and the total length of blanks drilled may be as much as twice the total length of the dug portions. It is not only that the percentage of dug trench is greater and the tunneling slower than drilling that makes drain trenching cost more than supply trenching of equal depth,—the trench for drains must be wider and the ramming takes more time and care. Some dirt will be left, especially on shallow trenches even if the line is small, if the ramming is not well done, and the pipe will be disturbed by filling in if it is not carefully rammed at the bottom.

An example of pocket-and-drilled trench is shown in section by Fig. 424, it being supposed to be a house-service trench beginning at the property line. The length of the first pocket, at the service, indicated by **A**, depends upon what kind of pipe is to be installed. For iron pipe, $\frac{3}{4}$-in. and less, the length of the first pocket must be at least half to three quarters that of a full factory length of pipe. For sizes larger than $\frac{3}{4}$-in. pocket **A** must be as long as a full length unless the depth is shallow,—it is not worth while to drill for depths less than two feet except under buildings or to avoid paving. If a pipe must be permanently sprung to get it down and into the drill hole it is likely to give

trouble when feeding it through the holes from pocket to pocket. So, it is really time saved to dig the first pocket full length for any size pipe. Blank space **C** may be any length up to 20 ft., according to length of trench, skill of the driller, his acquaintance with how the particular drill in use drifts, type of soil (whether it is sticky), whether "dead" stem holes can be avoided, etc. It is easier to screw the service lengths together in pocket **A** and shoving the line forward, as necessary, than to have to attach new lengths on the slant because of **A** being too short to take a length. Pocket **B** need never be over 4-ft. long for iron pipe. The length of **A** will take care of any drill stem needed, and the drill can

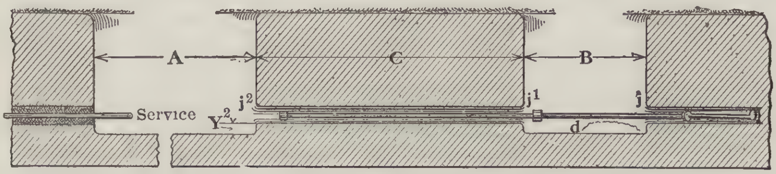


FIG. 424. LONGITUDINAL SECTION OF POCKET-AND-DRILLED TRENCH FOR SUPPLY PIPE

work through from one pocket to another. When long blanks for lead pipe are drilled, lengthening the drill stem is necessary, of course, and unless the space is figured on beforehand, pocket **B** is likely to be dug too far away from **A**. Lead pipe can be fed through the drill holes from pockets as short as one can dig or drill in, so for lead services no pocket need be over 4 ft. long, unless a 4-ft. drill stem is used. The second pocket of the series (**B**) should be drilled in first in order to save drilling a blind pocket for the lengthened drill-stem. If the drilling of blank **C** should be done from pocket **A**, for lead pipe, **A** would ordinarily not exceed 4-ft. in length and **C**, of normal length, would be 12 to 15-ft.; a 3-ft. stem and the drill would take up the length of **A**, after drilling 4-ft. in **C**, a blind hole would have to be drilled in the opposite direction so the lengthened stem could be withdrawn to empty the drill when continuing the work in **C**. An unnecessary blind hole is labor wasted, and can generally be avoided by beginning the drilling in the second pocket (**B**) of the series at the end in which the drill is shown in Fig. 424. All the drilling done in that direction is a part of that needed to place the pipe line and after first drilling, at **j**, to about the length of the stem, the drill can be reversed to $\mathbf{j}^1$ and worked into the length of the stem. A lengthening piece can then be added in order to double the depth in the direction of **A**. The drill hole in **C** is then long enough to permit using two lengthening pieces when drilling away from **C**, though drilling cannot be continued in **C** because hole **j** is too short. The first lengthening piece is therefore removed and the drill changed to hole **j**, where, with two additions, to the drill stem, its length may be increased to

12 ft. (the third pocket). By again reversing the drill, blank **C** can be drilled through to **j**[2].

On account of the stiffness of iron pipe and the holes always being more or less out of alignment, a 3-in. drill should be used, so the line will shove along and turn easily. A $2\frac{1}{2}$-in. drill 10 to 12 in. long, with $\frac{1}{2}$-in. pipe stem is best for lead pipe. A drill and stem is sketched in place in Fig. 424. The drill holes should be a little above the bottom of the pocket depth, as at **Y**[2], so the hand will have freedom in stabbing and also that there may be a little room for the dirt, shown at **d**, punched out of the drill. When drilling vertical holes there is a chance to tap the full drill against a clod or chunk of wood and thus cause the spring of the drill to compact the contents so the mass will drop out, but in horizontal drilling it is quicker work to shove the drillings out with a stick. Shoving the dirt out saves the wear and tear on the stem socket otherwise caused by jarring out. These drills are tapering pieces of sheet steel, formed up pipe-like and riveted to a pipe socket,—usually $\frac{1}{2}\times 1$-in. A little flare or cone shape is given the drill, mostly on the sides, so it will not bind in the hole,—the side edges of the sheet being about $\frac{1}{4}$-in. apart at the stem socket end and 1-in. or more at the cutting end. The cutting edge should be filed sharp, partly from both sides. Too much flare causes hard drilling as the material must thus be not only cut but forced into a greatly reduced section as the drill fills. The stem of the drill should align with the center line of the two ends of the drill. The flare should be mostly on the sides and front (the slot, gap, or open part is the front). The easiest straight working drills are, at the back, nearly parallel (but not in alignment) with the stem. If the drill drifts down too much or to the right or left, in practice, look to the beveling on the end or change the shape a little,—do not cant in on the stem if avoidable.

It is frequently easy and quick work,—money saved—to force a supply pipe through a short space, using a piercing spike, like shown in Fig. 425, screwed on to the supply,—**K** is the supply; **K**[1], the spike-socket, ground down some all around as at **K**[2], and, **K**[3] is the steel spike threaded and screwed into the socket so the pipe butts against the end of it. The size of the pipe shown is $\frac{1}{2}$ in. For larger sizes either a larger point should be made or a special socket used, as a common reducing pipe socket does not allow the pipe to butt the end of the point properly. By screwing a rod (solid) driving head and coupling on the end of the supply, short stretches can usually be easily hammered or mauled through with a hammer or beetle. If driving seems too severe, because the length of the pipe allows it to vibrate, time may be saved by driving short lengths,—3-ft. more or less.

If there is trench room, long pieces of small sizes can be forced in by using a portable pipe for gripping the pipe, setting it, say 2 ft. from

where the pipe is entering the earth. A 2×4-in. or heavier timber, footing against a block at the opposite end of the trench, can be used as a fulcrum and another piece, notched in the end so it will straddle the pipe a little and bear against the vise jaws at the pipe level, will answer as a lever of great power if the fulcrum is made to oppose it comparatively low down. This is illustrated by Fig. 426. Additional blocks can be dropped in at the end of the fulcrum, as the pipe is shoved along, until the vise has to be slipped back on the pipe so the performance can be repeated. A rack and cog-lever jack can be used instead of the common lever, adding blocks behind it or moving the vise back at intervals to equal the throw of the jack. In fact any means may be used that will bring effective pressure to bear on the pipe at a point and

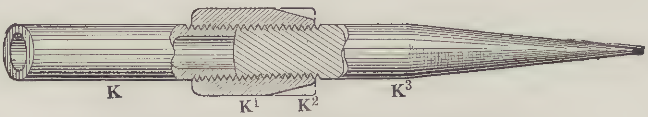


Fig. 425. Supply Pipe Driving Point

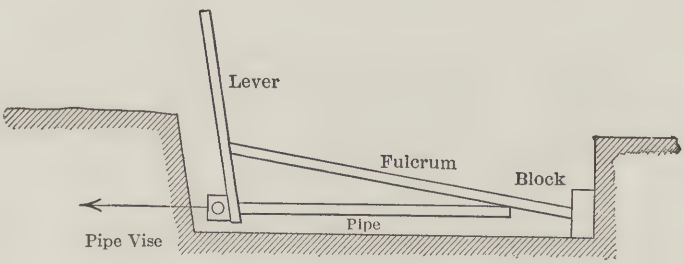


Fig. 426. Improvised Apparatus for Driving Supply Pipe Instead of Drilling or Trenching for it

in a way to force it forward without damaging the pipe. Any virgin strata free of rock, gravel and slate can be so pierced for a reasonable distance.

Clay drain tile is so large as compared to supply pipe, and the lengths so short that drilling, as for supplies, will not answer, though tunneling is commonly resorted to where the pipe is to be laid four or more feet deep, if power tools are not used. If iron soil pipe is being placed in earth, blanks of 6-ft. to 8-ft. can be partly tunnelled from each end and then bored with a common auger or knocked through with a post-hole digger or spade. The author has bored greater distances, but it is not easily done with market augers,—the cutting blades must have high lips parallel with the stem to keep the auger from drifting downward. Such is best provided by buying a larger auger than it is designed to use and then having a smith turn up an inch or so of the blades and shape them into effective lips curved to the arc of the diameter to be bored.

Fig. 427 illustrates a sectional perspective of a pocket-and-tunnelled trench. Distance **W** may be 4-ft. or more, according to depth and whether the lower dirt must be pitched to a platform and then out because of the depth. **R** may be 4-ft. or more according to the kind of pipe,—not over 6-ft. for clay pipe; **Z** distance should be only 18-in. to 2-ft. for clay pipe but may be any distance, according to circumstances, for iron pipe.

It is well to compare the expense of furnishing iron pipe and boring considerable of the trench from pocket to pocket, with that for clay pipe and short tunnels, on rather deep lines of 6-in. or less, before bidding on a job.

The ends of the tunnels between pockets can be roughly cut with

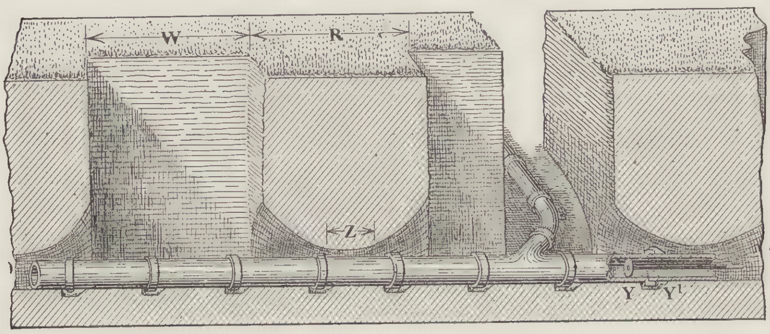


Fig. 427. Longitudinal Section of Pocket-and-Tunnel Trench for Sewers

a common spade but the center is best done with regular curved blade spades made for the purpose.

When laying drain pipe the body of each length should be laid on earth that has not been disturbed; that is, besides carefully grading to an undisturbed plane, a place for the hubs should be scooped out of the bottom of the trench. If this is not done, either ramming or the weight of the filling may break the joints or crack the hubs. If cracked hubs or broken joints result, tree roots will find their way in and choke the pipe. Roots extend themselves most rapidly in the direction of moisture,—it is part of their food—and once into the pipe they grow still more rapidly.

It may be well to state here that while Portland cement is the best when work is once properly completed with it, the setting is too long deferred to make it suitable for drain repairs that must go into service immediately or for new work that must be filled in within less than 24 hours. A quick setting cement should be used for all work that cannot be left unshaken for a day or more.

The surest way to have a pipe clear of cement, dirt and other foreign matter when finished, is to insert a tight-fitting plunger (shown at **Y**)

behind each joint before cementing, and withdraw it at the last moment before placing the next joint. No person in a hurry likes to do this because it means repeated mixing of small batches and cementing each joint as the pipe is laid,—the proper way. There is always some space for cement between the hub and spigot ends, though frequently not enough to easily shove the cement in from the outside. The lower third of the open hub should therefore be bedded with cement before the next length to be set is slipped over the plunger handle. The spigot end should be held up to the top of the hub space until the length has entered the hub the full distance. The spigot end may then be pressed down until the joint space is equalized and the balance of the joint space "wiped" full of cement. There is no cause to pile cement around the hub, as shown at Y^1, Fig. 427 if the hub and spigot ends are sound.

The plunger shown in the drawing is made of a disc of sole-leather fastened on a piece of $\frac{1}{2}$-in. pipe between two $\frac{7}{8}\times 2$-in. wrought washers held by two pipe lock-nuts.

The sketch shows a Y-fitting in the main line tilted up to meet a shallow branch line, the shallow ditch curving gradually down to the depth of the main trench, at the junction. What has been said should answer for all the directions anyone will need for laying ordinary lines of drain pipe.

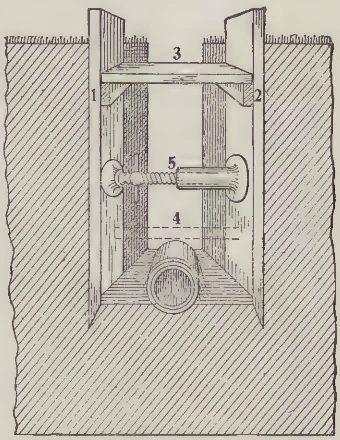


Fig. 428. Shoring at Intervals, without Stringers—Cross-sectional View

Fig. 428 is a section of trench showing a pair of shoring boards braced in without stringers. These are frequently so set, at intervals of a few feet, after the trench is finished, simply as a precaution against caving in, the lower ends being bedded in the earth and the upper ends held spread by the plank brace 3 resting on cleats 1 and 2. If the shoring is weak (too thin) or the trench deep, a second brace can be set at midway the whole depth, say at level 4, for a deeper trench. The pieces may be set before the trench is finished, if desired, and be tapped down with a maul as the depth increases.

A very good way to lightly sheath a trench, and one that offers some protection all along, is to place a 2×6, 10, or 12-in. board horizontally against each wall of the trench about $2\frac{1}{2}$ or 3 ft. from the top and fix them by bracing across the trench. Iron sewer braces like No. 5 in Fig. 428, though not essential, are the best for all narrow trenches and are very handy for setting the string boards mentioned. Pieces can be

set up over and under the stringers and the whole braced by uprights placed over them when the trench is finished, but this is considerable work and rarely done. Unless full shoring is placed, stringer boards along the sides or uprights, like shown, at intervals, are usually depended upon.

One pair of uprights like seen in Fig. 428 is often set up at the middle of the sides of trench pockets after the trenching is done. In other cases a 2×10-in. frame the size of the pocket is sunk flush with the surface at the beginning, and the pocket digging continued inside the frame without further protection. A ledge of earth the thickness of the boards is thus of course, left all around to support the frame in place.

A very ordinary practice in open trench work, not otherwise braced, is to employ a loose frame or cage 2×10 in. or lighter stuff in the trench to protect the man laying the pipe. The sides have a few strips nailed across to prevent a possible cave-in from crushing the staves together. The cage is moved back in the trench as the pipe laying progresses. If the trench is rammed from the bottom up instead of being soaked down with water, the same kind of cage is used to protect the man doing the ramming

Fig. 429 is a section of one side of a deep trench indicating the relative position of first and second lengths of continuous shoring, and some of the bracing. The shoring stuff is usually $1\frac{3}{4}$-in. thick, of random width, and of a length suited to dividing the total depth of shoring into two or more walls in a way to make sub-trenches, one excavated within the other and of a difference in width that leaves ample width for the lower side stringers of the shoring above and yet width enough for the work below. If the trench is wide, wood braces are cheapest and best. They are usually fitted, on the job, with a screw with swiveled head (see $\mathbf{f}^2$) working back into an augur hole in the timber through a plate nailed or bolted to the end of the brace. The braces, stanchions and stringers used are of any size suitable, from 4×4 or less to 12×12-in. Three stringers are generally used for each shoring depth. Two are set at once after trimming the walls to the safe depth dug without shoring,—one at the trench bottom and the other stanchioned up with braces swinging between and kept from falling by cleats as indicated in Fig. 429. These braces or others, placed later, with a screw on one end are set 5 to 6 ft. apart. Screw braces and others with cleats only are often alternated. The first bent of shoring is stood up behind the two stringers mentioned, board by board and finally backed up to the bank moderately tight with the screws. As the depth of the trench increases, each board is beetled down behind the stringers.

Taking $\mathbf{f}^2$, Fig. 429, as the third stringer, it would be laid upon the bottom (earth) or on blocks. Then, well within the stringer lines the

trench would be continued narrow enough to permit placing and driving down a second wall of sheathing without friction or interference from the stringers of the first, the whole proceedings of the work above being duplicated by stages, just as though another trench was being dug.

Another plan is to cut all the shoring into 4-ft. pieces and bevel the ends as at **f** and **f**[2], Fig. 429. When the trench is dug deep enough for one set, these pieces are placed like a solid upright fence, against the wall and braced, as described. Some preliminary shoring may be necessary for each depth following the first but the wall of sheathing is built under at the bottom and made continuous, in alignment from top to bottom, as often as the depth of the trench will admit the pieces. The bottom stringer of each set of pieces can be driven down to cover the laps, or a new stringer can be set beneath, as thought safest. Trenches 60 ft. deep and 6, 8 and 10-ft. wide have been handled by this method. A cheaper grade of sheathing lumber will answer for it and there is not so much excavating required.

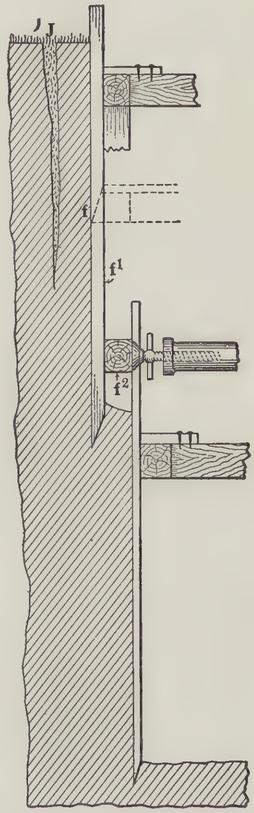


FIG. 429. CROSS-SECTION AT ONE SIDE OF TRENCH, ILLUSTRATING STRINGERS, STANCHIONS AND BRACES AS USED IN CONTINUOUS SHORING

Water trickling down behind shoring during a shower, frost, or other causes, is likely to unbalance the resistance of the walls of a trench. If it has been open some time the tensile strain on the earth may be more than its tenacity will stand without good support from the shoring and the weaker wall thus give back. This is certain to crack the surface on the other side and it may cause a crack on both sides. Such crevices should be watched for and kept tamped up with dry sand. The sand will fill to the bottom and helps to re-establish the resistance of the ground by giving a continuous mass for the opposite wall to thrust against. In the sketch, the crack **J** is shown close to the trench wall. In practice it would appear at from $\frac{1}{3}$ the depth of the trench away, to distances as great as where the angle of repose would reach the surface. If a crack is narrow, look for the second and third, farther away.

It is a bad plan to dig a trench to random depth and then grade it. The total fall and grade must be found ultimately and it is quicker and makes a better and cheaper job to dispense with guess work at the outset. Guessing at the grade results in digging too deep in spots and

then refilling to the grade line. The filled places are not a sound support like the balance and allow the line to settle some, with all the consequences before mentioned.

The total fall may be found with a builder's level or with a carpenter's level and long leveling board, moving and blocking up to the

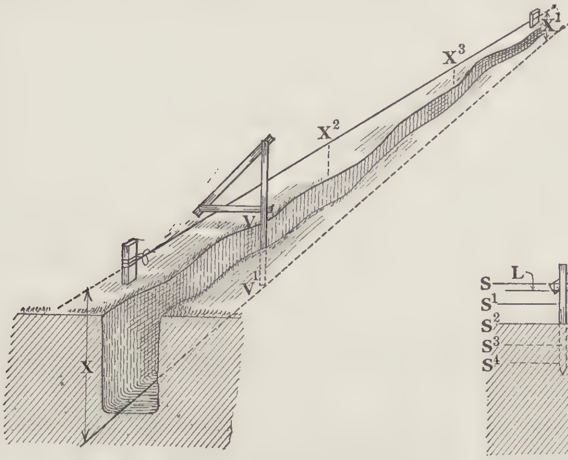


Fig. 430. Perspective of Trench Illustrating Method of Grading by Inclined Line

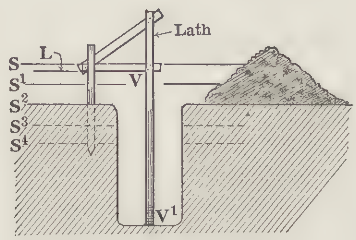


Fig. 431. Cross Section of Fig. 430

high level to the end of the course, or dropping down, from time to time, and keeping accounts of the changes of level.

Perhaps setting the level board once at the high end and sighting, to the low point or outlet station, will establish the fact that there is a liberal fall. Then, if there are no cross pipes in the course to be gone under or over the plan shown in Fig. 430 is the simplest and one that a stupid laborer cannot make an error on after the ground is staked out for him. It consists of placing a stake at each end of the course and stretching a line between. The line at the high end is fastened about the stake at some certain distance above the pipe's starting point; at the low end it is secured to the stake an equal distance above the pipe line finishing level. The dotted line in the sketch represents the bottom of the trench with a fall equal to the difference in levels,—**X** and **X**^{1} are therefore of equal height from the trench bottom. The line, stake to stake, is inclined equal to the total fall,—the line is therefore the same distance above the trench bottom at all points. There is then nothing to do but dig and grade the trench to the depth of **X** below the line at all points. A stick with an arm, **V**, nailed on at right-angles, at **X** distance from end **V**^{1}, and braced to keep it square, all as shown, is the easiest means of testing the trench depth while digging. Regardless of the surface contour it is only necessary to set **V**^{1} end on the trench bottom and hold the leg **v**-**v**^{1} upright,—if the arm touches the line, the depth is

right. Fig. 431 is a cross-section of the trench, etc., shown in Fig. 430, **L** being the line level; **S** to **S**[4] may be taken as the ground height at different points along the trench. On long stretches it is necessary to drive intermediate stakes, as $\mathbf{X}^2$ and $\mathbf{X}^3$ in order to fasten the line up without sag. The line may be sighted after stretching, between the main stakes and pulled up at the low places by a wire hooked under it. When the line is straight, the wire can be bent down over the top of the stake to keep it so.

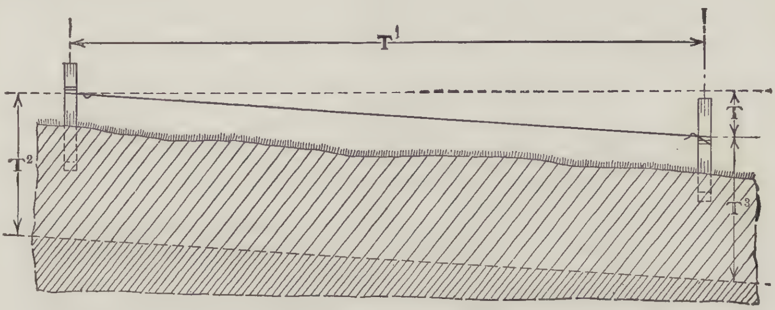


FIG. 432. STAKE AND LINE GRADING BY SECTIONS—SIDE SECTIONAL VIEW

Fig. 432 is a side section view of the trenching method shown in Figs. 430 and 431, further illustrating the grades of line and trench. Sometimes, on account of the contour of the surface or because other pipes cross the course of a drain line, it becomes necessary to lay different portions of a pipe line at different grades. The fall required between points to go over or under obstructions being found, each section of the trench can be treated as described for Fig. 430. Taking Fig. 432 as a section of such a trench, the fall in $\mathbf{T}^1$ length is equal to **T**. Vertical distances $\mathbf{T}^2$ and $\mathbf{T}^3$ are equal. The line and the trench bottom are parallel and the line has the fall allowable for the section represented by the length $\mathbf{T}^1$.

CHAPTER LXXXII

Dynamite Ditching

Dynamite, has its limitations of course, just as other methods, and its value depends upon the discrimination with which it is employed. It is cheap work per cubic foot removed, but, if employed where it accomplishes too much unnecessary removal and thereby adds to the cost of refilling—if refilling is necessary,—it would entail a loss instead of producing a gain. Consider a 100 foot trench in open flat ground where either process might be employed: to dig alone, $1\frac{1}{2}$ ft. wide and 3 ft. deep would excavate 450 cu. ft. To dynamite, at about the same cost, say 27 cents per cubic yard, would remove 900 cu. ft. To fill the dug trench would be easy and cheap; to refill the dynamite ditch would be more expensive, both as to volume and to the collection of the dirt which would be distributed over a territory extending four times as far as that covered when the dirt is heaved out by hand. For farm underdrainage, irrigating, etc., where an upheaval of the soil is beneficial; for pond and reservoir excavation; the initial work on cellars and cisterns; for trenching for farm or other surface drainage; for pipe trenching where the line must pass through cuts in knobby or rolling ground,—where one to three ranges variously loaded may be fired in the same territory to make the cut; for pulling out excessively hard clay strata; for initial cutting for deep trenches where part of the work may be thus accomplished, leaving sides with approximate angle of repose and reducing or making unnecessary the feature of shoring up,—in all of these and more instances dynamite may be employed with economy varying from sufficient to make it an object, to a matter of remarkable saving.

As best suited to give an idea of dynamite ditching the result of a fuse-fired range in flat, damp, open ground is shown in Fig. 435. The sides of the ditch may be said to always practically include an angle of 90 deg. The burden lifted is of course in the lines of least resistance, modified by the effect of cohesion of the earth. Near the surface, the earth is torn out to some depth a foot or more beyond the general ditch lines, due to the action of cohesion force, where there is no superincumbent weight to maintain the general line of fracture. The earth removed is scattered 25 ft. or more, and is cloddy according to the kind and dampness.

As the side or a dynamite ditch is 45 deg. from the perpendicular, the depth is always equal to the sine of that angle. The length of slant side is equal to the diagonal of a square the side of which equals the de-

sired depth of ditch. Depth desired multiplied by 1.414 will give the length of slant side and the distance to sink the loading holes. Also, depth multiplied by 2 will give the surface width of ditch and, the depth multiplied by the depth gives the cross-sectional area of the ditch. Example: Ditch is to be 36 in. deep, what will be length of side, length of loading hole, width and area of ditch? Answer: $36 \times 1.414 = 51$ in.,—slant side, *and* length of loading holes; 51×1.414, or $36 \times 2 = 72$,—width of ditch at surface. 36×36 or $72 \times 18 = 1296$ sq. in. sectional area,—

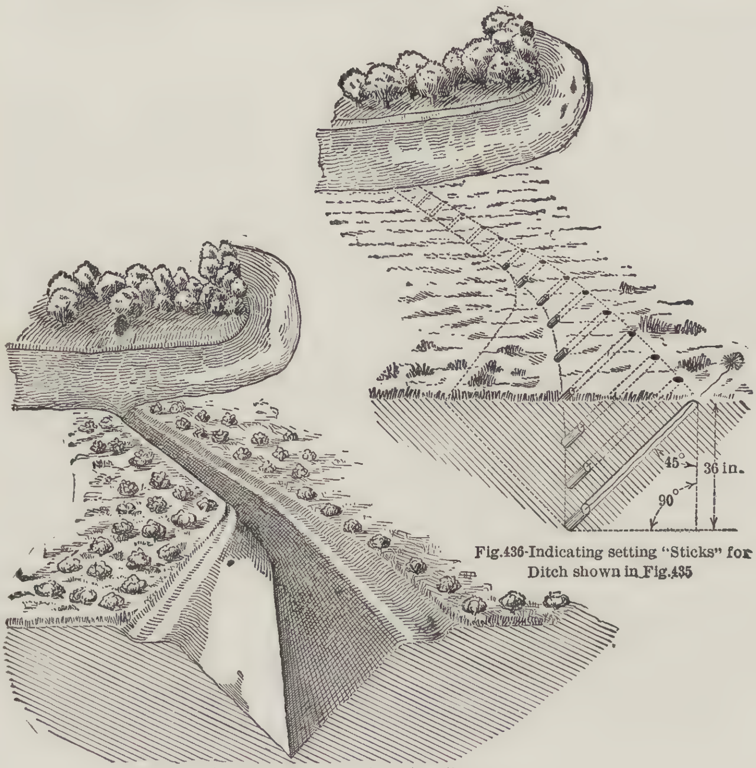


Fig.436-Indicating setting "Sticks" for Ditch shown in Fig.435

Fig.435-Ditch after explosion in wet earth

FIGS. 435–436. DYNAMITE TRENCHING

square feet, 9 cu. ft. per lineal foot of ditch. It will be seen from this that there need be no guess work in plotting ranges for either ditch work of single or multiple ranges nor for the general breaking up of surface,—depth, extent and volume are deducible beforehand.

Rock holes are filled and tamped as the resistance of rock would otherwise cause the charge to blow out of the hole. The sticks used for rock may be what are termed No. 1-40 (40 per cent. nitroglycerine). Those serving best in earth are No. 1-60. These sticks are about 8 in. long and either $1\frac{1}{8}$ or $1\frac{1}{4}$-in. diameter. The $1\frac{1}{8}$-in. sticks are most used,

and no attempt to tamp the holes is made, though filling could not but do some good and no harm if the time could not be otherwise better employed.

Shooting holes in earth are placed at an angle of 45 deg. and begin at the surface at a distance from the center of the ditch equal the required ditch depth. Fig. 436 illustrates the modus operandi of preparation for shooting a range, the result of which is shown in Fig. 435. The line of holes have been drilled along what is to be one edge of the ditch, at

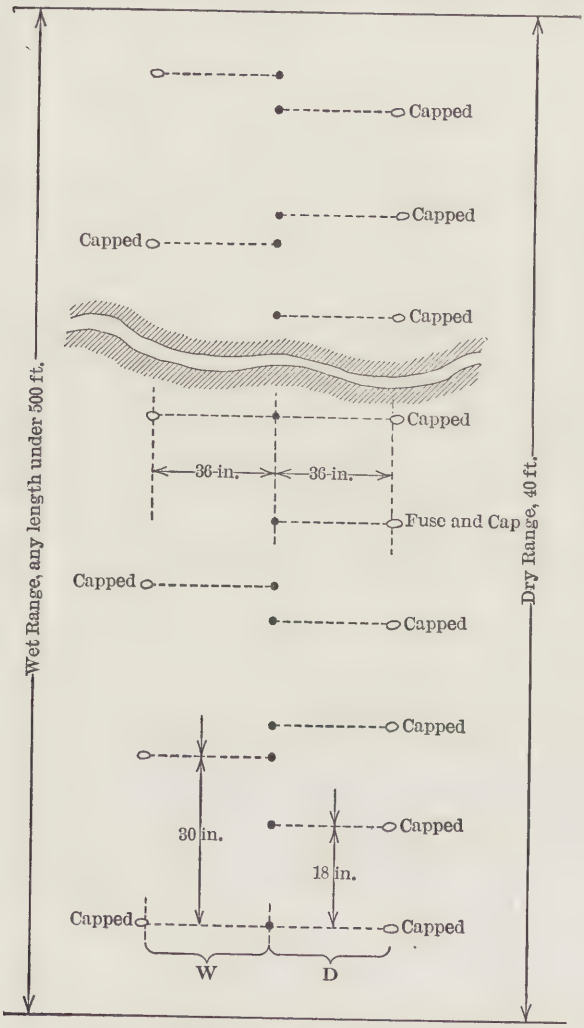


FIG. 437 DRY and WET FUSE-FIRING RANGES

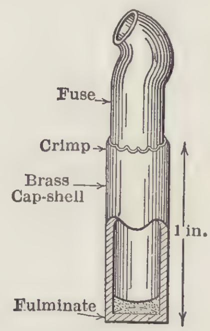


FIG. 438. CAP SHOWING FUSE ENTERED

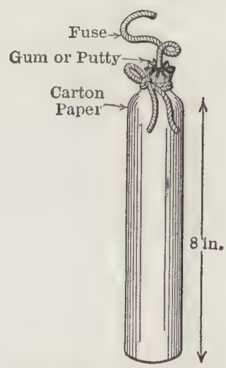


FIG. 439. "STICK" WITH CAP AND FUSE TIED IN

the angle stated, and to a depth that will place the sticks under the center of the burden to be lifted. Why slanting the holes at right angles to the course of trench does better, the author has not been able to altogether figure out. The result *is* better,—the whole length of one side

of the stick is in this position backed up by maximum resistance—dirt that has not been and is not disturbed at all at any stage of the upheaval —while if the holes were aligned *with* the ditch course, the explosion shock, though to the eye instantaneous throughout the range, would break up the solidity of the mass to some extent and not leave a seating of maximum resistance to any quarter of the stick's cylinder surface. The disposition of the holes as to distance apart, etc., is better shown in Fig. 437 in which **W** represents a range laid out over wet earth, and **D** the same over comparatively dry earth,—30 in. apart being the maximum and 18 in. the minimum for earth varying from moist to very wet, bordering on sogginess. The wetter earth is the better it shoots, while if bone dry the result is for most purposes not worth the while. The effect may be enhanced in "dry" earth by pouring the holes full of water a number of times. This soaks and clods a pod at the bottom, which conserves the force of the explosion enough to drive better and also offers some clinging masses to follow up and push the dry stuff ahead. Where the strata is extremely soggy the distance 30 in. may be exceeded some, especially if shooting by current, but where the shock of one stick, fuse-fired, is depended upon to jar off the next, and it in turn, the next, and so on, it is better not to fuse every hole, even if it cost nothing. Where shock firing fails, there is no danger; the break in the firing is evident, there is no hang-fire fuse to set off the remaining sticks just as the operator thinks investigation is dead safe.

The safety and convenience of cap and fuse firing has established the method for general miscellaneous use on small jobs. That the shock from one stick will fire the one adjacent, and so on, led to the employment of one fuse to the range, and as placing the fuse in the center hole reduces the percentage of unfired holes in case of a break in firing it is generally so placed, as indicated in the dry range in Fig. 437. This applies to all fuse-fired ranges. Though a fuse could be placed at each end, both would not be likely to be effective. The fuse is made to approximately burn one foot per minute, but in practice one of the two for many reasons would fire the range including the stick of the second fuse, so about its only chance would be to finish the range in case of a break in the shock-firing.

"While but one fuse is used, *every* stick is capped in 'dry' earth and the range limited to 40 or 50 ft.; in 'wet' earth," says Richard Gray, "every other stick is capped (all may be as extra precaution) and the range length is practically without limit." All this is indicated in Fig. 437.

There is nothing in dynamite work that need deter the veriest novice from using it, nor that will hinder him from getting results. It *does* require experience to get the best results; cautiousness as with anything else, to avoid hurting any one, and good judgment in order to reason from condition to condition, and thus apply effectively what is learned on one

shot to the conditions for another, and so, early in the game, be able to get the best results. No hard and fast rules for charging can be given. One of experience makes all sorts of combinations of distance and quantity. That is, he will judge the wetness, from working the holes, and in one case put in one $1\frac{1}{8}$-in. stick to the hole, holes 30 in. apart; in another he will place the same, 18 in. apart; in another, one $1\frac{1}{4}$-in. stick to the hole 30-in. apart; in another, two $1\frac{1}{4}$-in. sticks or one $1\frac{1}{4}$ and $1\frac{1}{8}$ stick (always capping the upper stick only) to the hole, 24 in. apart,—wetness of earth, depth of ditch and distance apart of holes all being duly considered in making the decision. As before indicated, one $1\frac{1}{8}$-in. stick to the hole at proper distance will easily lift and thoroughly clear the ditch of from 13 to 22 cu. ft., according to wetness, at a depth of 36 in. For ditches of other sections, the charge should be fairly proportional.

The caps, before mentioned, are brass shells about $\frac{1}{4}$-in. diameter and one inch long; cost 50 cents per 100; water-proof double taped fuse burning one foot per minute, cost $\frac{7}{10}$-cent per foot; dynamite cost 15 cents per pound,—100 $1\frac{1}{8}$-in. sticks per box of 50 lbs. In the bottom of the cap is a layer of fulminate like in gun caps; the end of the fuse, freshly cut, is forced down into the cap tight against it and the top of the cap-shell crimped in tight against the fuse to keep the fuse end from pulling away from the fulminate,—all as shown in Fig. 438. Enough of the fuse is then cut off with the cap to reach from the stick to well above the ground. The carton paper at end of stick is then opened and a hole punched in the end of the dynamite, by wiggling the end of a hard smooth peg into it about the depth of the cap,—a stick shaped like the end of a tapering pen holder will answer to make the holes with. The cap is then pushed down into the dynamite and the carton paper tied tight around the fuse over it as shown in Fig. 439,—this is to keep the fuse from pulling out as the stick is lowered into the hole. A little chewing gum, putty, or axle grease should be placed around the fuse where the paper crimps to it, to keep water from getting in. This constitutes "capping and fusing" a stick. For capping only, the cap is merely sunk in the stick and the paper closed over it.

In Fig. 440 are shown different types of drills that can be used in earth. The octagon steel shown at **A** is harder on the hands than round steel. The weight of the shank is generally enough to sink the drill, it being turned between jabs so as to strike the width of the bit at a different angle at every stroke. More or less water is used in the holes while drilling according to dryness, and a wet swab is used to clear the hole and work out loosened substance. When loading holes they should be first swabbed out, and one should be sure the sticks go down full depth. When a fuse is attached, the length of fuse will show whether the stick is *down*. A pointed rod as indicated at **B** will answer for making holes, but it offers friction against the hole its entire length. The

bit end shown at **B′** is usual, it being much like a quarry bit,—swelled to exceed the bar diameter by flattening down the end. The character of the bit really makes no difference for earth work, clearance for the bar is the only point that may be considered essential. In theory the drill shown at **C** would seem to be ideal, but while the bar is free, it is *light* and often needs tapping; also, the bar being small, it is hard to grip, and its radial leverage being reduced with the diameter makes it hard to twist in the hole.

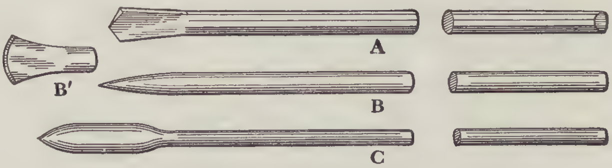


FIG. 440. TYPES OF "DRILLS" USED IN EARTH

Electric shooting is practiced by many who have sufficient work to pay for equipment, but it is doubtful whether it pays on any ordinary work. For exploding with current "shooters" of different lengths can be had. These take the place of the ordinary cap and fuse. The "shooter" is a cap with two wires attached, the wires being long enough

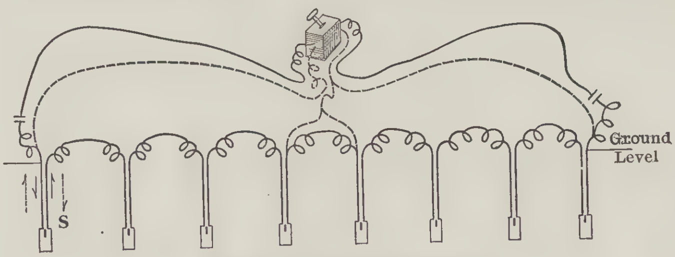


FIG. 442. ELECTRIC SHOOTING

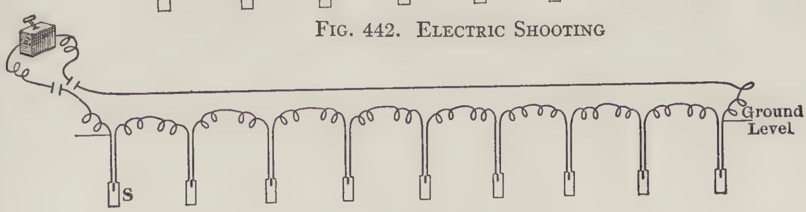


FIG. 443. ELECTRIC SHOOTING

to reach well out of the hole. The sticks are loaded as usual, with the "shooters" in place of caps and the sticks dropped into place. The shooter wires are then extended and joined, one to the other, leaving one wire free at each end of the range, all as shown in Fig. 442, being careful that no bare parts are in contact with each other or any other conductor. The lead wires from the machine shown by solid lines, are then attached to the free end wires. A stroke of the handle at the machine will then

fire the range. If preferred the range can be fired in multiple by arranging the wires as indicated by the dotted lines in Fig. 442. A point to be observed is that of keeping the lead wires out of the ditch territory as much as possible to avoid shooting them to pieces. If a feed wire followed the range as indicated in Fig. 443, it would likely be skinned of insulating and broken up by the explosion so as to be fit only for connecting shooters.

Stumps and various other obstructions often need to be moved. This can be done as indicated in Fig. 441. If it is desired to pitch the obstruction in a certain direction, its center of gravity must be on *that*

FIG. 441. "PITCHING" OBSTRUCTIONS OUT OF TRENCH LINE

side of the stick's position, as indicated by **Z** in the sketch. If the stick penetrates too far under a stump as at **X** it is likely to shoot the dirt out and leave the stump. To make sure that unexpected roots or one with unusual strength does not swing the stump in a contrary direction, cut those that show on the hole side, as at **a** and **b**, Fig. 441. The fewest and smallest roots are generally on the northwest side of a stump. It is useless to try to lift a stump with a big tap root,—such as may be found with hickory, shell-bark hickory, and some kinds of pine,—by placing dynamite in earth. Make the hole as usual until tap root is struck; then bore into it with a stump auger and place the stick in the wood of the root. This will literally blow the root apart.

PART V

CHAPTER LXXXIII

The Topographical Factor in Estimating

A man of sufficient experience and business capacity in the trade to bring him into contact with good work will generally have no trouble in arbitrarily fixing the labor cost of excavating, for ordinary sewers, supply lines, etc., by the factor of his experience or that of others in common trenching, so long as the ground is level or has a general slope one way. When a contour is rolling or knobby some care to find the volume of material to be moved is necessary; if rock is known, or found by sounding, to be within the trench lines, greater accuracy than for earth estimating is demanded to get the work on a paying basis, or lose it on sensible grounds instead of being too high or too low from lack of careful estimating. Cheap sounding may be done by driving a steel rod the required depth at intervals along the course of trench.

In country and suburban work the trenching is a more important item than for cramped city quarters; the surface contour is in virgin state; the distances to well, waterfall, sewage, outfall, etc., likely to be great; rock or slate may abound; paved roadways and drives may cross the course of lines, and favorite shade trees, great expanses of lawn and sacred timber groves are frequent, and the whole gamut must be contended with at the pleasure of the owner. These features are not to be looked upon as annoyances,—they are incidents of the job; priceless or indispensable environment of the home without which the owner would likely want no plumbing, for country seat attractions are not of a nature to be sacrificed to the commercial advantages of plumbing. In this sort of work there is generally available, a topographical map of the premises,—made to show in a plane surface,—that of the map paper—by the aid of surveying and kindred processes, the physical features and contour of the ground of the premises. Detail marks may vary but the map is as a rule furnished with a key of symbols, so that no extended mention of indicative marks is here necessary. Such maps are usually neither strictly cadastral nor topographical but generally show accurately to a comparatively large scale the location (and a diagram) of buildings; roads; streams; location, kind, diameter of body and sweep of foliage of every tree and shrub, in addition to discovering the contour of the ground in definite directions through iso-elevation lines figured to indicate the progressive increment or diminution of height.

On account of the expense of extreme accuracy, these charts for

private purposes may differ widely from the completeness of governmental practice and are made simply to serve the purpose. Fig. 450 is of a residence plot and represents a portion of a topographical map of

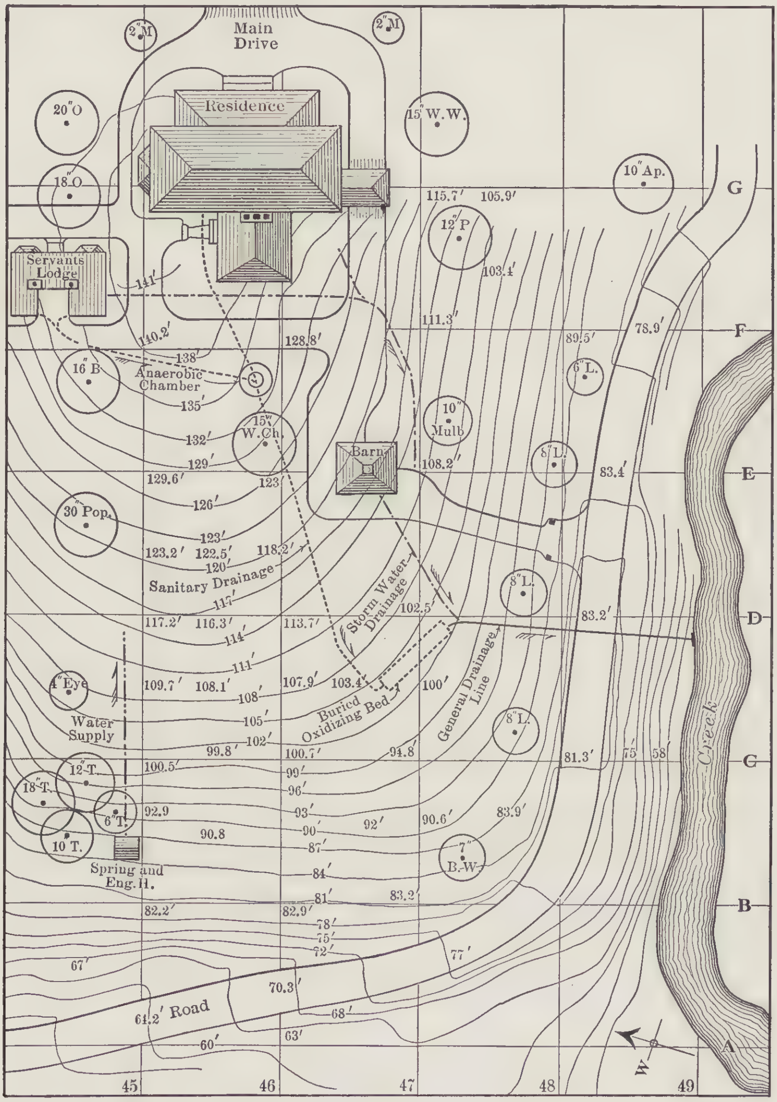


FIG. 450. TOPOGRAPHICAL SKETCH WITH DRAINAGE AND SANITARY SEWERAGE OF BUILDINGS INDICATED

a larger tract than shown. Such work without the proper instruments would be very tedious, but with a stadia instrument, distances may be read through the telescope without measuring, and with note book in

hand, one can swing the instrument from tree to tree, and point to point over quite a little territory from a single station; duplicate notes of the same object detect themselves in plotting. For distance reading, two stadia wires are fixed parallel in the field of the telescope. The relation the distance between the wires bears to the distance from the wires to a point at the eye-piece is used to determine the distance from instrument to rod, through the relations they bear to the distance between the points where the wires cut the rod and the distance of rod from instrument. This is easily understood when it is remembered that two lines separating a given distance, say $\frac{2}{10}$ (about 1 deg.) in 12 in., will separate $\frac{4}{10}$ in two feet; $\frac{6}{10}$ in three, 1 in. in five feet, and so on.

Referring to the sketch figures, **A**, **B**, **C** and 49, 48, 47, etc., are marginal reference letters for locating points by the intersection of their lines,—for example: "Sugar maple at 45-F, interfering with cistern, will be transplanted at E-47." The contour lines are each supposed to traverse courses of equal elevation, that for each being given in the break in the line. The figures from which these lines were developed are shown along the sectioning lines and in their squares. The datum for these levels may be a selected point. In this case, it is a sea-level with the odd hundreds of feet plot-datum dropped from the figures given. Dots represent tree bodies, and by which are given the diameter of the body in inches and initial of the name. The circles while exaggerated direct attention to the body and approximately indicate the relative spread of limbs.

Fig. 450 is from a topograph, the ground scale of which is 50 feet to the inch. The course traversed by the elevation lines makes it easy for the eye to note relative steepness of surface in different directions and their separation betrays the change in gradients to some extent without noting the figures. A little study enables one to frame a very good idea of the average depth necessary for a trench when conditions such as shown prevail, but for part rock, or knobby courses it is best to make a section of the course,—scaling it by plot distance and contouring by the elevation given.

Dotted in on the map is a septic sewage disposal plant, the dotted lines being for the sanitary drainage, and dash-and-dot lines for storm water pipes.

A Plumber's Improvised Leveling Outfit

With reference to finding relative levels, the following incident is valuable for the suggestion of what one may accomplish when restricted to individual resources and the commonest of tools.

"Are you figuring the Newrich job?" inquired a competitor. "No, it will need immediate attention and I cannot give it." "Then," observed the competitor, who was a genteel conscientious fellow that

would never dream of taking undue advantage, even though he was handicapped to some extent by a phlegmatic temperament. "You are probably in position to offer some valuable suggestions,—if you are inclined to favor me?" "Not likely, as I hav'n't gone into the matter at all seriously, but I would aid you if I could. It occurred to me, I might say, that the successful bid for that job would depend largely on the skill in estimating the excavation,—the specifications (there are no plans for the drainage) say, 'Shall have uniform grade, not less in any instance than one-fourth inch to the foot.' This does not imply that any line shall be given the same fall from end to end, and a little leveling work to find what the chords of average depth would require removing from those bumpy slopes ought to go a long way toward landing the job if it could be done without furnishing a clue to others." "Oh, thank you, that is just the hint necessary and worth coming a long trip for," was the response.

The next day, being called to a country job by a road which led past the Newrich premises, what at first appeared to be a civil engineer at work on the slope above the creek proved at a closer view to be Mr. Competitor and his man Friday.

The tripod seen at a distance, disappeared at first but was produced again when he recognized the visitor. It was his camera tripod to which was attached by means of a screw-eye, a new 30-in. carpenter's level with globe sights. From the screw-eye, hung a plumb which served to establish the height of level; in its suspending cord were three loops marking one, two and three feet up—from ground,—thus affording an approximate gauge by which to measure level with the tape from instrument to rod,—holding up on the cord according to the reading. The "rod" was a $2 \times 1\frac{3}{8}$-in.

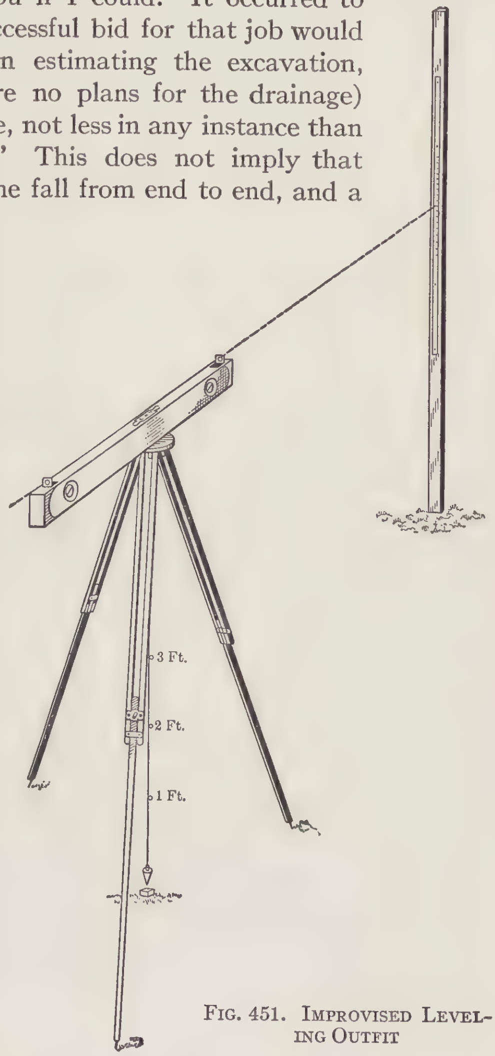


FIG. 451. IMPROVISED LEVELING OUTFIT

yellow-poplar strip with two 2-ft. pocket rules bradded to it and meeting at "instrument height,"—one reading 1, 2, 3, up, the other down. 1, 2, 3, down. In his memorandum book he was entering the "down" and "up" readings,—preliminary to working a profile for determining the gradients of the line. A pocket compass was furnishing the means of recording direction. The "outfit" is shown in Fig. 451.

Of course no regular engineer or surveyor would use feet and inch divisions except in cases of the direst necessity. Tenths and hundredths of feet graduations simplify the calculations marvelously, having decimally the same advantage over feet and inches as U. S. money has over pounds, shillings and pence. Cheap flexible tapes divided into tenths, that can be, at will, tacked to any sort of rod and removed and carried, rolled, in the pocket, can be had.

Figuring Trench Work from Topographic Map

The solid line **B** to **A**, Fig. 452 follows the figures on the topo-lines of Fig. 451. The course gives a rather regular contour to the eye and is not a good example by which to show the advantages of so developing grades. The course of drain indicated by **a** to **h** is in decidedly rougher ground, the contour of which is from a different map, and shown roughly dotted in on the same ordinates and to the same scale,—50 ft. per inch. The contour, 141 to 132 is given as the same in both maps, while 132 to 12, indicated by dotted lines, is much steeper and broken. What datum the figures refer to is of little consequence to the estimator. The relative levels of various points affecting the work is about all he cares about. The levels being shown in feet by the figures, and the horizontal distances being to a scale, the relation of levels, and distance from point to point can easily be determined.

The first step in making the section shown was to draw the line at the bottom (base) representing, at all points, the lowest ground level on the map. Perpendicular to this the ordinates were erected so as to cut the topo-lines on the map at the route line,—the tracing paper having been laid over the map, far enough away to permit setting off, to the scale, the highest elevation to be used. The same result would have been obtained by measuring (or stepping with dividers) the distance between topo-lines along the trench or pipe route, setting off same, in like order, on the bottom line, and erecting vertical lines (ordinates) from these points. With the distances between ordinates thus established to the same scale as the map, the next step is to mark a point on each ordinate, representing, to the scale of the map, the elevation of that point above the low-level line, as indicated by the corresponding topo-line (line on the map traversing points of equal elevation). If the low-level used is above datum (not zero on the map) the low-level elevation will have to be subtracted from each other elevation used in order to

obtain the distances to set off by scale on the ordinates. The same result may follow from making the ordinates long enough to set off on them, to scale, the whole distance from datum indicated to levels given. The figures given on the ordinates in the section are "feet elevation" above the low-level,—plot datum in this case.

To follow the surface represented by levels 12 ft. to 132 ft., keeping a uniform frost depth below surface, with proper fall at the level spots might be an effective, but not a workman-like job. The actual surface is not so smooth and regular as a small scale section makes it appear and in some cases is much more broken than shown. The profile of surface shows the principal ups and downs, helps to determine better pipe grades, shows where saving in trench work may be accomplished suggests the amount of "shoring up" that may be necessary and gives the length of pipe.

In the pipe line drawn in on the section, Fig. 452, are six changes of grade, approximating the surface, and marked by **b**, **c**, **d**, **e**, **f** and **g**. Though the grades shown do not do so, the object was, in this, as in all similar work, to establish such as would give the least work consistent with a good job. This example is not to be taken as a measure of the benefit accruing from such practice, but rather as a basis for explaining the mode of work. Including with grade **d-e** the distance from 54 ft. *next 56 ft.* to 54 ft. *next 46 ft.*, would have made less work; extending grade **b-c** to reach frost depth at ordinate 135 ft. would have increased the work.

Having the section laid out to scale with all necessary figures jotted on it, the question of quantity of material to be excavated might be approached in several ways. Some would doubtless use the algebraic sum rule for trench side-area, but the easiest plan is to follow the simple old-fashioned method here given. It will not be necessary, for illustration, to figure more than the trench contents between a single pair of ordinates. To do this, in detail, with the best result, section **b-c** of the trench has been enlarged and set over the general section, with some extra data added, as shown. Side area of the trench from ordinate to ordinate, is the first requisite, and the first step in finding same will generally be to remember the rule for areas of triangles and apply same to the chunk of trench in hand, as follows: the sense of the rule is—*Half the base of any triangle multiplied by its vertical height gives a product equal to the area;* this is just the same as saying: *The base of any triangle multiplied by half its vertical height gives a product equal to the area;* these propositions are equally true whether the apex of the triangle is *over* the base or somewhere far or near to the right or left. As proof let us test, with the triangles indicated in the rhomboid parallelogram **V-V′ X-X′**, sketched between ordinates 112-98 in the detail, taking the distance between ordinates, 24 ft., as the *vertical* height or *altitude*. For

X-X′V′, the base is thus 3 ft., and the altitude 24 ft.; for **V-V′X** the base is $4\frac{1}{2}$ ft. and altitude 24 ft. Then by the first proposition: $1\frac{1}{2}\times24+2\frac{1}{4}\times24=90$; by the second way of putting it: $3\times12=36$; $4\frac{1}{2}\times12=54$; $54+36=90$, the square feet area in side of trench from ordinate 112 ft. to ordinate 98 ft.; but, it is quicker to employ a shorter equivalent of the foregoing,—viz.—"the mean ordinate height (or mean vertical depth) of trench multiplied by the horizontal distance between ordinates," thus: $3+4\frac{1}{2}=7\frac{1}{2}$; $7\frac{1}{2}\div2=3\frac{3}{4}$,—mean vertical depth; $3\frac{3}{4}\times24=90$, the same as obtained by adding the areas of the component tri-

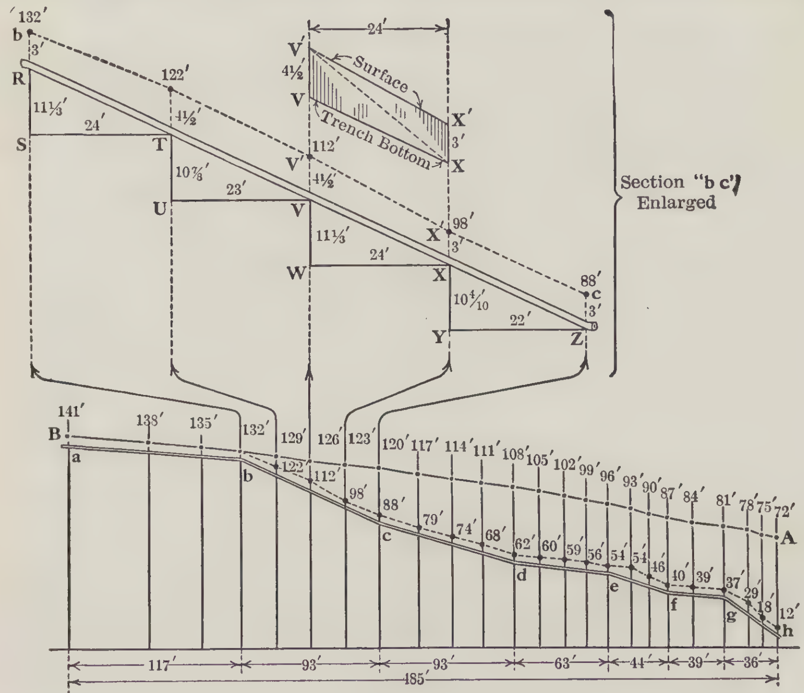


FIG. 452. TWO SURFACE CONTOURS DEVELOPED FROM TOPOGRAPHIC MAPS

angles. Having the side area of a section of trench in square feet it is only necessary to multiply by the width of trench in feet, to obtain the cubic feet in that section, which, divided by 27 gives the cubic yards. If the trench is 2 ft. wide, we have 180 cu. ft. or $6\frac{2}{3}$ cu. yds. for the section in question,—if $1\frac{1}{2}$ ft. wide, 135 cu. ft. or 5 cu. yds. The material to be excavated from other sections is found in the same way.

The length of trench bottom for the grade **b-c** is equal to the square root of sum of the total fall of the grade, squared, plus the horizontal distance covered by the grade, squared, thus: total fall, $44\times44=1936$; $93\times93=8649$; $8649+1936=10585$; $\sqrt{10585}=102.28$ ft.—the hypothenuse, **RZ** or **RS** and **ZY** extended to intersection. The trench bottom

fall between each pair of ordinates is found by subtracting the lesser ordinate elevation less the depth of trench, from the greater elevation less the depth of trench. To find the hypothenuse for the distance between the single pairs of ordinates is unnecessary,—an entire grade being the same fall per foot regardless of the number of ordinates embraced, the total fall for the grade answers for the altitude (fall) and horizontal distance stands for the base of the triangle, the hypothenuse of which is equal to the length of the trench bottom for the section. In the sketch, **R-S**, **T-U**, **V-W** and **XY** aggregate the total fall (44 ft.) of grade **b-c**; **S-T**, **U-V**, **W-X** and **Y-Z** make up 93 ft. the horizontal distance covered by **b-c**. All of these figures are approximate and merely intended to illustrate the method of procedure.

CHAPTER LXXXIV

Reading Plans

Both the estimating and installation of new work, and of most remodeling jobs requires the ability to read plans. For rapid and accurate estimating one must be able to promptly erect for the mind's eye, from the plans and elevations, a mental image of the structure complete, or of divers parts of it, from various points of sight, as occasion suggests; for pipe work there must be added to the mental picture of the structure, the mind's imagery of the plumbing work. To install work as the job progresses, a workman would be utterly at sea without such ability as he must finish ahead of construction largely by interpretation of the drawings in the shape of mental imagery of completed work not yet begun.

A pen, wash or air brush picture of the building in perspective in black and white or colors is not an unusual feature of the architect's skill, especially in residential work, but such is not essential, and the time so spent would often be more profitable if put into further general elaboration, large detail working drawings, etc., for the most complete commercial plans and specifications still leaves much not drawn and, left unsaid.

While plans may be made to carry definite depiction to the utmost degree ever wished for, and to interpret specifications to a point limiting their essentials to a mere skeleton of formality, it is too much to expect more in this line than the architects are already giving. The cost of complete plans and specifications for common work is prohibitive, and the common omissions resulting have a good effect in two ways. The limitations brought about by price and tactically agreed to by all give the owner more for his money. And, to insure that the spirit and evident intention are lived up to along with the letter in filling the gaps architects and owners are both obliged to let out the work to capable men,—men whose pride in name, standard of workmanship, conception of the fitness of things, etc., assure, beforehand, that the job will be as good in every way, and perhaps better than if the architect had specified every detail with the greatest of care. This is all true of plumbing and kindred work to an unusual degree. The plumber's directions are further abridged than those of any other line of work, and the high standing of the trade today is doubtless largely due to the fact that the plumber has not been dependent,—that he has had to draw upon his own resources in many directions, and that through it all he has been in a great measure on his honor as a man and workman. He has, in the past,

therefore, accomplished, to the lasting good of the calling, a higher mission than that of simply executing the other fellow's designs. But, while in certain classes of work such independence will continue, it has, for much city work of the present and future been merely a stepping stone in conjunction with other trades in setting up a new standard of efficiency for the vast building undertakings that followed. In many of these, carrying out the other fellow's design will be sufficient glory; in the co-extended middle class work where the discretion of the plumber has more latitude there is room enough to keep the wits aler in all the use of plans is becoming more and more general. The maker sends out exact blue print plans of his goods to "rough-in" by; for lack of wood the use of brick and stone is more extensive; the substitution of steel and concrete for other materials has multiplied plans and caused need for frequent reference to their provisions, for the finishing trades work thus made necessary. The framing used in many buildings requires more exact plans than formerly and for the same reason the workman must follow them closer; the plumber finds need to not only read plans but to make them as a part of his business, for either the building or sanitary department of most cities now require plans of the plumber, when he proposes work of any kind not covered by accredited architects or engineers, and no plumber is privileged to execute work without so obtaining the consent of the department.

All this is sufficient to show that plan reading is an essential to any tradesman worthy of being called a mechanic.

The accompanying plans are not supposed to have any merit considered as house plans to build by, though many people live in worse shacks than they would make. In order to have all of the views assembled in a way to best show the relation of one to another, most of the details, like dimensions and names of rooms,—framing indications, etc., were omitted, the walls drawn heavier than scale dimensions and the finish of frames, etc., merely approximated. The exterior features go further than ordinary toward naming the elevations and in the small size shown these general elevations give more picture effect than is found in full size house plans of any scale. In regular work no attempt is made to give form to features of plans and elevations by shading or perspective,—the elevations are for that purpose,—to develop the width, height and extension of parts as well of the structure in its entirety.

Fig. 455 is the first floor plan of the house shown. "Plan" is from the latin, *Planus*, flat or level, a graphic delineation in a horizontal plane. A "Floor" ("story," "flat" or "loft," according to locality) as understood and employed in house plans is not strictly that alone which appears in the horizontal plane at the floor level,—the shape of building is diagrammed to a scale at the floor level but windows, stairs, out-

side steps, porch floors, doors, plumbing fixtures, and so on, all to the scale and all in different horizontal planes are also indicated, as shown. The names of rooms, their actual size, joists and bridging, and headers, are also usually placed on floor plans. If no elevations are made, the size of windows and doors, style, and height of windows from floor etc., are added. If general elevations are made, all of the plan work that they show (door and window heights, etc.) conclusively can be omitted from the plans; if framing elevations are also made, the general elevations are in turn relieved of much that can be and often is indicated on them.

While the plan of one floor shows the size and layout of what is designed to appear thereon and may indicate things above and below the floor level, it gives no idea of the disposition of the space on another floor, nor of how high above or distant below, the other things shown or known to be above or below may be. This is true of the floor plans given and of every other plan view unless figures are added. Chimney flues are shown in Fig. 455. If any of these are not to extend as low as the fire-place throat, the height to which that portion is to be solid should, in the absence of a sectional elevation of the chimney, be written on the plan. The roof of portico and bay are shown with second floor plan, Fig. 456. These are the only exterior juttings, below the cornice, not shown on Fig. 455. They could not be shown, nor indicated on the first floor without the needless confusion of *dotting in* the first floor work as appearing *under* the roof, or dotting the roof lines to be understood as being *over*.

Fig. 457 is the roof plan. It shows the over-hang of cornice and that the roof has no deck, hips or valleys,—none of which is indicated by the floor plans. Though these lines could be dotted in over the floor plan, it is not regular to do so. All the juttings of the house are shown on Fig. 457. These fix the limit of projection when producing the elevations necessary to mark heights and positions of plan features impossible to be shown by a plan. Plans are generally used on the job as separate sheets, but in drawing them, they are so disposed on the board that when a position or length for one is found it can be located on all by the same line or lines instead of measuring and setting the tee-square for each floor or elevation the feature shows on. However the side and end elevations may be disposed on the drawing board, the usual and proper relation to the planes represented is shown by the manner in which Figs. 458 to 461 inclusive, are assembled about Fig. 457. Except that they are spread so as not to lap, their positions are much as though the sides and ends of the building had been hinged at the cornice and the foot of each wall pulled outward from the building so as to let the roof down between them. The juttings quickly tell the eye which side each elevation represents and would do so by the aid of the floor plans, with-

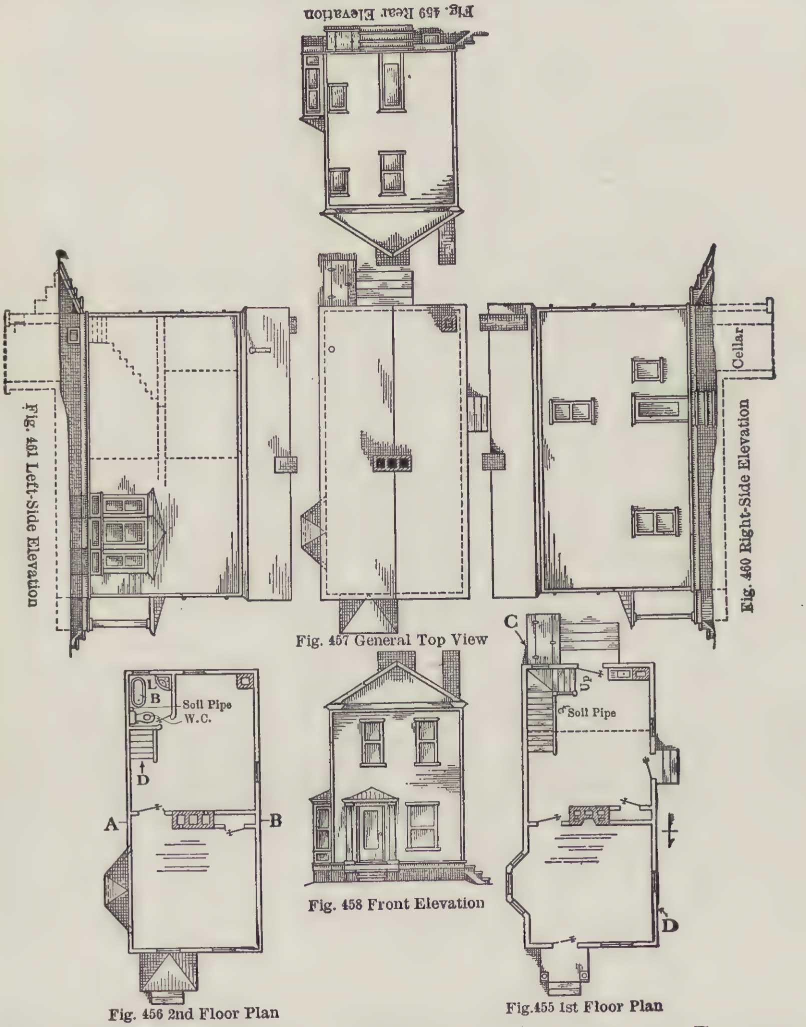
out Fig. 457,—even were the outer walls blank, the chimney flue alone on either the roof or floor plans would show which side or end a view or elevatiôn was drawn from.

The width and depth of buildings usually distinguish sides from ends in the elevations. If the plans or front elevation is marked "Front," then the other general elevations are "right-side," "left-side" and "rear"; if the building faces one of the cardinal points or is intermediate and the plan shows the points of compass, the elevations may be marked "Front," "West," "East," and "South," or "South-west," "South-east," "North-west" and "North-east," or, however the faces of the building may demand. "Transverse" for across front or rear, and "longitudinal" for from front to rear, though proper and usual for machinery and other drawings, are awkward terms for house plans aside from naming sections, as "transverse vertical section," or, "longitudinal," etc. If a section is developed on a specific plane, named by letters and an indicative line, as "—— on line **AB**, Fig. ——," the position of the plane so defined shows without qualification whether it is transverse or otherwise. Letter definition is shorter for all, always specific, and must be resorted to for oblique planes, say as for a vertical section on line **CD**, Fig. 455. The general elevations of ends and sides of a building are made to show in true scale length and position all that would appear of each to the eye, supposing the eye to cover the whole plane,—that is, that the line of vision is at all points and perpendicular to all points shown. The relation of the features of Figs. 458 to 461 or of other elevations, is therefore to their principal vertical planes, about as the parts of a floor plan are to its plane,—all oblique parts, in both, that recede or approach from the principal plane are fore-shortened in proportion to the angle and are thus seen as though in the same plane with the balance. Framing plans and elevations show only the framing members, in about the fashion already described. The stairway, second floor level, cellar, etc., are dotted in one of the elevations shown, but, strictly, these belong to framing or sectional elevations.

The subject of drawing is so vast, that only a few points relating to a single branch can be mentioned in a limited space, for even a work of several volumes has failed to do the subject justice in some respects. The best course for the average person is to study drawings and illustrations, wherever found; the house plans used by mechanics from day to day are the best examples for gaining a knowledge of the architectural work with which they are ever in contact; text book illustrations are generally good examples of the art; trade paper diagrams have no equal in suggestive values, for though the iron-clad rules of drawing are, in them, often violated, they are snappy and effective, and teach resourcefulness to a degree not dreamed of in school graphics. To all these

sources of information, the beginner should, if he can afford to, add at least one good work covering drawing in all its branches.

House plans are generally made to $\frac{1}{4}$-in. scale. If the building is very large, the general plans may be to the scale of $\frac{1}{8}$-in. equal 1-ft.



FIGS. 455–461. PLAN READING,—THE PLANS AND ELEVATIONS OF A TWO-STORY FRAME DWELLING

At $\frac{1}{8}$-in. scale, 8 ft. equal 1-in. length on the plan,—other lengths are proportional,—4 in. are 32 ft. at $\frac{1}{8}$-in. scale, and but 16 ft. at $\frac{1}{4}$-in., because there are $\frac{32}{8}$ or $\frac{16}{4}$ in 4 in.

An architect's scale rule provides for easily setting off any distance in feet and inches, to any ordinary scale. For the $\frac{1}{8}$-in. scale, $\frac{1}{8}$-in. is divided into 12 parts, each part ($\frac{1}{96}$ in.) being equal to 1-in. in a scale of

$\frac{1}{8}$-in. to the foot,—this provides for the odd inches of measurements; then, on, from this graduated $\frac{1}{8}$, the balance of that particular face of the rule is marked in eighths, and numbered. Other scales are graduated in the same way on other faces of the rule,—for $\frac{3}{16}$-in. scale, the $\frac{3}{16}$ in. are divided into 12 parts, each making about $\frac{1}{64}$ in. length for an inch at $\frac{3}{16}$ in. to the foot scale, and so on; 1-in. at $\frac{1}{4}$-in. scale being $\frac{1}{48}$-in.; at $\frac{3}{8}$-in. scale, $\frac{1}{32}$ in.; at $\frac{1}{2}$-in., $\frac{1}{24}$; at $\frac{3}{4}$-in., $\frac{1}{16}$ in.; at 1-in., $\frac{1}{12}$ in.; at $1\frac{1}{2}$-in., $\frac{1}{8}$ in., and at 3-in. equal 1-ft., 1-in. equals $\frac{1}{4}$-in. In these larger scales, for detail work, the fraction of an inch equaling 1-in. at the scale is large enough to subdivide; for instance, at 3-in. scale, the $\frac{1}{4}$-in. equaling 1-in., is, or can be divided into: $\frac{3}{4}$-in. actual length equal $\frac{3}{16}$-in. scale; $\frac{1}{2}$-in. $\frac{1}{8}$-in.; $\frac{1}{4}$ in., $\frac{1}{16}$ in. and $\frac{1}{8}$ in. actual length (of house or article) equals $\frac{1}{32}$-in.

As duplicates of original drawings are necessary, the originals are traced in india ink on transparent paper or linen. These tracings are used as negatives to make black, blue or sepia prints, the prints having white lines on ground of the colors mentioned, or lines in the color used, on white ground, all according to the paper, chemicals and treatment employed. The prints so made are monotones and the work of coloring parts to symbolize the various materials represented would be prohibitive on more than one score. Materials of different kinds are therefore lined in a standard manner so that anyone familiar with the conventions of drawing may, as a rule, easily recognize the various materials by their plan treatment.

Plans often bear a schedule of conventional marking. Some of the usual marks are: Wood, white, or side or end grain, according as it shows; stone, pen stippled; shingles, courses with joints broken; brick, coursed, or coursed and hatched diagonally one way, or, diagonally hatched one way on plans and parallel open level lines on elevations; terra cotta, white, marked **TC** on elevations, and web form on plans; concrete, diagonal hatched two ways, or stipple and random egg ovals and triangles to represent gravel and broken rock; cast iron sections, light close diagonal hatching one way; wrought iron, light and heavy diagonal lines, alternating one way; glass, broken section-lining showing blank patches: fire-proofing, section-lined margin with stippled center.

For coloring drawings, yellow is used for wood-work; red for brick; glass, new blue or light green; steel and iron, prussian blue; stone, raw umber or pale sepia; terra cotta, burned umber; slate, indigo; plaster, grey; concrete, grey-mottled or sepia with black dots; earth, burnt umber.

Dimension lines are solid continuous lines or long dashes, and if the kind of drawing permits, are often in colored ink to distinguish them from plan parts; center lines are alternate dot and dash,—these are generally in color on drawings having the dimension lines colored, and should be a different color from that of the dimension lines.

CHAPTER LXXXV

The Diagrams and Composite Plans of Estimating

Disproportionableness will mar either the looks or utility of almost anything, and pipe diagrams are not the exception, for lack of proportion and absence of system in this work are two points that characterize the average workman's effort to use graphic aid with his figures in a way to better preserve a record of what has been or is to be done. The fact that lines are resorted to is evidence that, however poorly used, they aid in telling the story; the further fact that by proportion, established symbols and methods, lines can in the least possible time be made to precisely tell practically the whole story without letters shows that the value of diagrams is to no small degree dependent upon system and proportion and that the benefit to be derived by any craft is worth the study necessary to the adoption of such methods as have proven to be adequate for the purpose. This is especially true in the plumbing trade, for in it records prevent errors and imposition in very many ways, and of all tradesmen the plumber probably takes the least precaution against possible mishaps, errors in estimating, aftermaths from changes without record or order, etc., any of which may involve him, after which he finds the law is on the side of legal records and general orderly conduct of business. Architects, owners, builders, manufacturers and jobbers all see, in *their* interest, that the plumber leaves nothing unsaid or undone that may cause *them* expense. But, the plumber generally objects to nothing, agrees to everything, takes every chance and wades in, often without so much as a detailed estimate of the goods he presumes will be required to do the job, depending frequently upon an undated unsigned memorandum as a basis of cost of the goods, in lieu of a regularly rendered quotation specifying the goods and stating the latest date at which they will be supplied at the prices quoted. No sort of system will end the plumber's troubles, but careful records can bring about the condition of Greek opposing Greek, and this much every tradesman owes to himself.

The author is far from advocating any elaborate method of accounting, estimating or diagramming,—too much system will kill a business as fast as too little attention to it will; the object of business is profit; it will not do to spend all of the profit in red tape methods disguised as system; a system must fit the business; if the character or volume of the business changes, change or elaborate the system so as to keep it effective; when sure that some feature of a system is not and never will be worth its cost, omit it in the beginning or lop it off as you would a losing

game of any other character; endeavor to live up to a limited system embracing the essential safe-guard against loss,—this will include a reasonable amount of precaution in the shape of estimate records, diagrams, quotations and memoranda conscientiously taken care of,—an irksome task in the most meager system that will be effective, but one which if omitted will soon butt the business into something that will prove a little system worth its cost.

For estimating, the author depends upon a simple plan of which the sketches herewith illustrate the principles at length. Though the description and sketches necessary to convey the idea of practical general application are at least seemingly complex the whole, as used in shop practice is simple and easily rendered.

It may as well be stated at the outset that no abridgement of proper methods, nor combination of tools or articles can ever be faultless. The poor 10-cent-6-tool combination has its field of usefulness and the public would not dispense with it, yet it is a poor substitute for any of the articles represented; a flat dweller would prefer a combination piano-refrigerator to none at all; so with the plumber,—any method is better than none, but in this plan the evils of abridgement, in drawing, etc., are much less than ordinary.

Scale drawings or diagrams done to a nicety, by any method, are not to be considered for this purpose as the condition under which the work is usually done are not only prohibitive in point of time and equipment, but are unnecessary. Figs. 465 to 466 show the fixtures in a residence job, in plan position, and on their respective floors. If the floor plots were on transparent paper and the fixtures in black lines, the fixtures would show in the relative position indicated in Fig. 469, if the plots were placed one over the other in 1, 2, 3 order. On small jobs it is a matter of discretion as to the diagrams made, but where there are many and scattered fixtures, the first step in estimating is usually the production of a rough composite plan of the fixtures, like Fig. 469, especially if the soil, storm water, grease lines and waste are to be carried in separate systems, or even in more than one system of pipe. Soil and some of the waste is often carried separately where the septic process is to be employed; lines having grease in the waste are generally kept separate until the grease has been trapped out, and, the storm water is frequently piped entirely independent of the plumbing. Such conditions multiply the stacks and laterals and alone make it difficult to "take off" the material without something to check back on. In large buildings the architect provides a schedule of fixtures and indicates more or less of the stack and lateral work, but even in this class of work a composite plan is a great help. It is the bulk of ordinary jobs, however, that the author has in mind while speaking of diagramming,—jobs that have usually little more than the fixture outlines, aside from

the specifications, and which have from 10 to 75 fixtures. The making of the composite plan is 30 minutes or less for any ordinary job. Cheap transparent paper will answer; if no sort of tracing paper is at hand, carbon paper can be laid upon any other kind and the plans laid upon the carbon, one at a time, pinning down each in turn with the principal corners of the building at the same points those of the first plan covered. A hard pencil or stylo will do to trace the fixture outlines, and a different color or carbon should be used for each floor, or, the outlines may

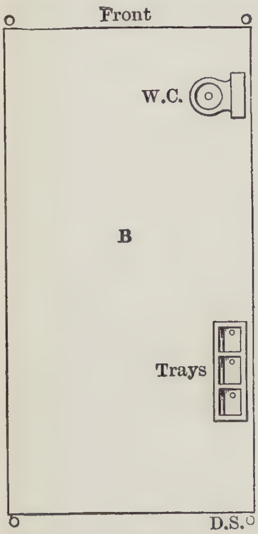


FIG. 465. BASEMENT PLOT WITH FIXTURES INDICATED

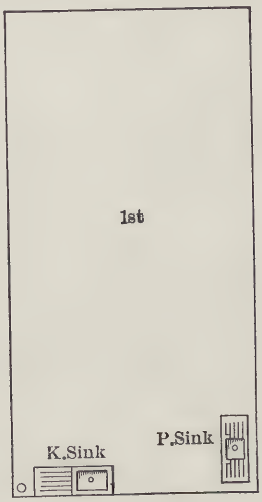


FIG. 466. FIRST FLOOR PLOT

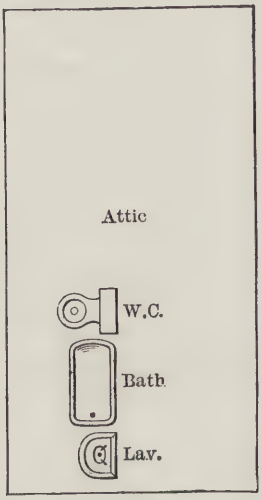


FIG. 467. SECOND FLOOR PLOT

be hatched, cross-hatched, dotted, etc., in a way to distinguish the fixtures and lines of the respective floors. If tracing paper is to be used lay it over the basement plan first and trace around the architect's images of any fixtures marked thereon, using ink or pencil. Mark the main corners of the building and then place the tracing in position over the first floor plan and outline the fixtures on it with a pencil or ink of a different color. If colors are not at hand, hatch the outlines so the fixtures of each floor can be readily singled out from the others at a glance, and so, on, for each floor that has fixtures. Fig. 469 was made in this way. Instead of hatching, the floors may be indicated within the fixture outlines as, say by placing a "B" on basement fixtures, "1st," on first floor; "2nd," on second floor fixtures, etc. One color of pencil, ink, or carbon may be used if necessary, and the outlines colored with colored pencils or ink, afterward. In Fig. 469 the basement fixtures are openly section-lined (cross-hatched) both ways; the first floor fixtures are section-lined one way; the second floor fixtures are diagrammed in solid lines and the attic fixtures in dotted lines. In full size plans, detail

can be suggested, if desired,—the lavatory bowl, back and bowl waste-hole, the closet flush rim and outlet hole, and the rim of tubs are indicated, in Fig. 469 but are not necessary. Waste and supplies in or behind the rim of tubs, basin standing wastes, etc., can be shown by heavy dots, and stacks that show on each floor can be circled where the uprights come, at will. Aside from the estimate items, this plan is usually the only thing the plumber has at hand to refer to at least until the work is under way, and, detail marks, whether shown by the architect or filled in from memory, after or while reading the specifications, help to determine the course of lines and list of material and are sometimes of value otherwise.

When this system is first inaugurated, a schedule of the colors, hatching, or conventional outlines should be marked on the composite plan. After it has been long followed, adopted floor symbols will be so fixed in mind that only the necessary departures from regular marking need be scheduled. The architect's plans are drawn to a scale,—the composite plan and all its forms are therefore to the same scale as the house plan and the fixtures on it are in relative position, thus aiding in electing the course of the stack or stacks and showing just where vertical parts can be brought through the floors without conflict with the fixtures. The advantage of a record like Fig. 469 is not limited to these points. It helps in making and interpreting the soil-pipe working diagram shown in Figs. 471 and 472 and, being to the house plan scale, and a part of a regular plan of doing business, it is conclusive evidence of the number and kind of fixtures on each floor, their location, etc., according to the plans by which the bid was made. So, if any change is subsequently made in the house walls, partitions, fixtures or location of fixtures, by the architect, owner or builder, before or after the house has been commenced, this diagram is mute (legal if necessary) evidence of just what was bid on. If extras based on such changes cause dispute, the plumber is able to show that it is his habit to proceed along the lines evidenced by his plans and diagrams, made prior to the contract and as a basis to bid on. This leaves little doubt as to whether the plumber is entitled to extra for a change. As an instance of the value of having such positive information on hand:—the second floor of a house proved to be altogether different from the original plan when it came to installing the work. The journeyman reported that the diagram did not agree with the house, and asked for instructions. The plumber was flatly disputed by owner, architect and builder, in the beginning, but, upon exhibiting his estimate diagram and composite plan, the architect recognized them as having been made from a print of a discarded second floor layout. It was revealed that the plans had at one time gone so far as to have blue prints made from the tracings before the owner found fault with the second floor arrangement. Inference pointed so

strongly to the fact that, in making up sets of blue prints for the bidders a print made from a tracing of the discarded plan was, by error, made up in the set handed the plumber to estimate on, that all hands were ready to admit the plumber was right in his connection and that he should have extra pay for the additional expense incurred by working to the revised plan.

The piping of the job shown is on the "continuous" plan,—one stack carries the soil, waste (grease lines included) and storm water. The

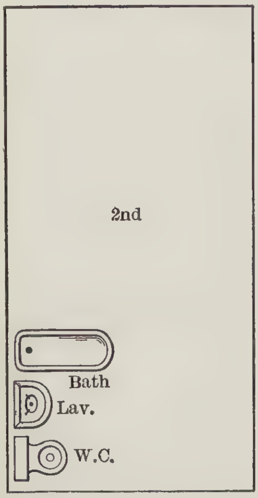


FIG. 468. ATTIC FLOOR PLOT

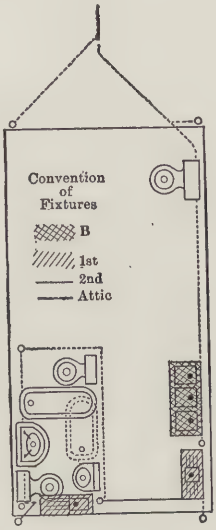


FIG. 469. COMPOSITE PLAN OF FIXTURES

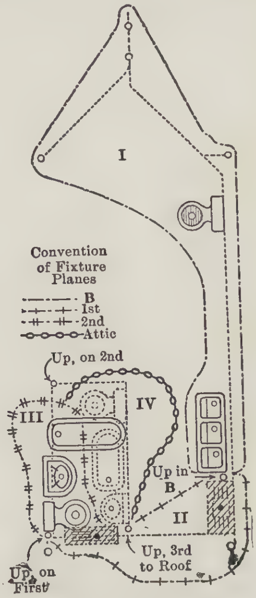


FIG. 470. PIPE AND FIXTURE PLANES

vertical and lateral portions are all indicated in plan, Fig. 469, which to some might answer without a diagram. Fig. 470, is not an essential and serves no purpose *here* but to inclose the fixture planes of Fig. 469. The fixture planes are often ringed in the composite plan by conventional lines, as in Fig. 470, but, to have so treated Fig. 469, in its small dimensions, would have caused confusion, and Fig. 470 was made merely to supplement Fig. 469 with a feature common to such work. When bidding, Fig. 469 is the only pipe work done for small jobs as the fixtures, pipe and fittings can from it be summed up accurately enough. If the job is secured the figure number of each fixture is marked by its form, and the lines, if not in ink, are roughly filled in, free-hand, with india ink,—any other information is also added that may be valuable to journeymen on the job.

When a diagram of the soil pipe is to be made, the method illustrated in Figs. 471 and 472 is followed. Frequently no measuring at all is done, the whole being drawn free-hand,—proportioned and angled by the eye,

as was Fig. 472. The aim should be, whether accomplished or not, to give all lines representing pipe, about the same length as they show in the composite plan; then their length is to the scale of the house plans and the advantages of proportional length are ever present.

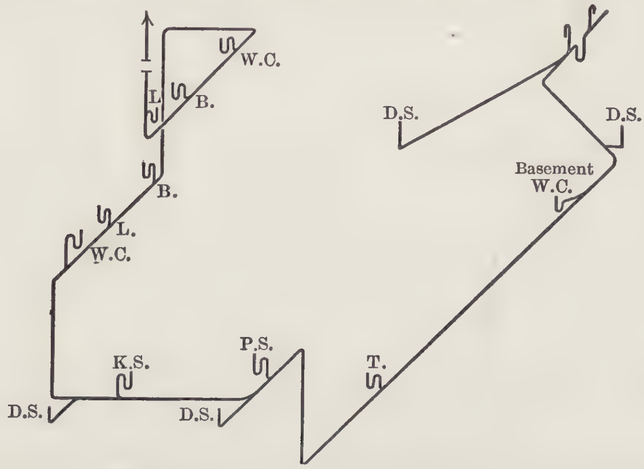


FIG. 471. ESTIMATOR'S DIAGRAM OF JOB SHOWN DRAWN METHODICALLY, BUT PROPORTIONED BY THE EYE

So long as the point of sight is marked on the diagram, it makes no difference as to what direction the job is diagrammed from, other than that taking one side, front or rear may give a better looking diagram than

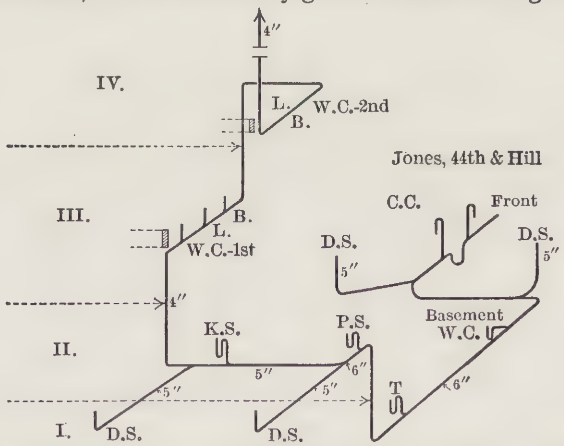


FIG. 472. JOURNEYMAN'S DIAGRAM OF SOIL, LEADER AND VENT PIPING MADE FREE-HAND BY METHOD SHOWN

could be obtained from the other points. The angle of the lines shown (45 deg.) is the same as used in making gas pipe diagrams, but, instead of putting all the pipes (lines representing them) of each horizontal plane perpendicular to each other, and connecting the several planes by

oblique lines representing vertical pipe, as is done for gas pipe, the vertical lines are made to represent vertical pipe and to meet at right angles, or, obliquely, other lines representing horizontal pipe. This conforms to what is termed oblique projection, an example of which is indicated in Fig. 474. Figs. 471 and 472 were drawn from the rear of the building. All lines in them representing vertical pipe run up and down as in ordinary elevations; all other lines represent horizontal pipe; all lines or sets of lines joining a vertical line at one or both ends are in the same horizontal plane; all lines from right to left are horizontal pipe crossing or running from front to back of the building, according to the position from which the diagram is made. Selecting any vertical line, then any line drawn obliquely from it, to the right, recedes from the person,—is beyond the position of the vertical pipe; any line drawn obliquely from it, to the left, approaches the person,—is nearer than the position of the vertical pipe or line; the usual departure of the oblique lines from the vertical, is 45 deg. It may be 30 deg. if desired. This is about all the directions needed to begin with,—experience will soon teach the beginner a few points that only experience can give. In Fig. 472 the fixture planes indicated in Fig. 470 are separated by dotted lines and numbered, to show more clearly what is meant by "fixture planes."

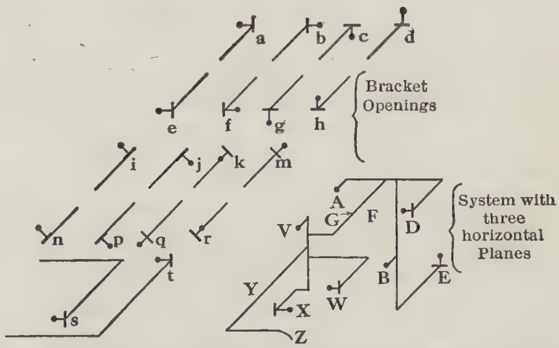


FIG. 473. SHOWING DIFFERENCE BETWEEN PLUMBING AND GAS PIPE DIAGRAMMING METHODS—COMPARE WITH FIGS. 470-472

The gas pipe method of diagramming, contrasted with that just described, is as follows: In gas work, fixture openings all come in or at the end of vertical pipe; it is easy to indicate the way a gas bracket opening looks by giving its fitting a plan position; this could not be done so easy by the method shown in Fig. 471, so in gas work, the vertical pipes are made oblique and the horizontal pipes drawn perpendicular to each other in plan position, as shown at the right in Fig. 473. The effect of plan position for drop ells drawn at the ends of rising and drop pipes is illustrated at the left in Fig. 473. By this method, **a** looks to the left, **b** to right, **c** to front and **d** to rear,—all on rising pipes; **e** to left, **f** to right, **g** to front and **h** to rear,—all on drop pipes; for octagon indications: **i** looks to left-rear, **j** to right-front, **k** to left-front and **m** to right-rear,—all on rising pipes; **n** to left-rear, **p** to right-front, **q** to left-

front and **r** to right-rear,—all on drop pipes; **s** looks to left on a drop pipe leading from a level pipe above; **t** looks to the left on a rising pipe leading from a level pipe below. All this presumes the diagram to have been made from the front of the building; the faces of the octagons from which **i** to **r** look are read by the plan position of the drop ells. In the 3-plane system, at the right in Fig. 473, **Z** is the run from cellar to

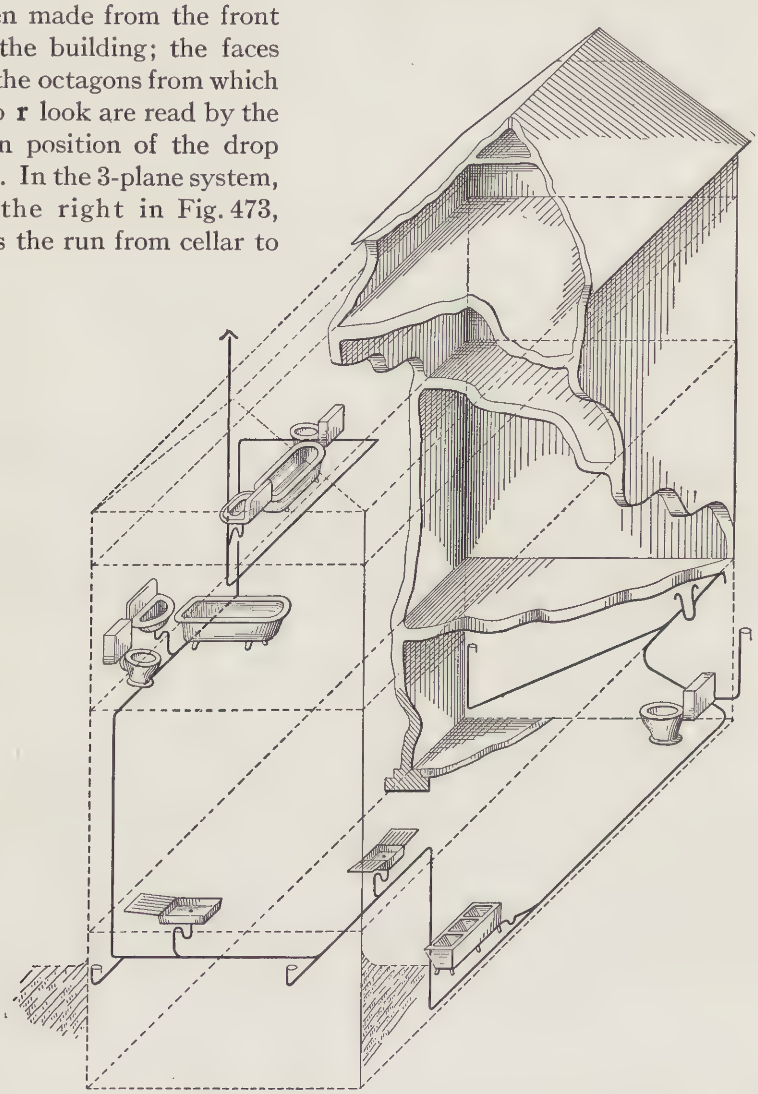


FIG. 474. CUBE OR OBLIQUE PROJECTION FROM REAR OF BUILDING WITH SOIL SYSTEM IN SOLID LINES AND PLUMBING FIXTURES SKETCHED IN

riser: **Y**, the riser; **V**, a center drop; **W** and **X**, drop brackets; other lines perpendicular to each other between **Y** and **G**, horizontal pipe, all in the same plane, between second floor joists; **G**, second floor riser; **F**, a hall light opening in it; **A** and **B**, center drops; **D**, a bracket opening

dropped to second floor; **E**, a bracket pipe rising to a third floor room; other lines perpendicular to each other and connected to the upper end of **G** are level pipe in the second floor ceiling joists. All the laterals in all the diagrams are drawn at the same angle and presumed to have the proper fall,—the angle of the oblique lines for gas diagrams being almost invariably 45 deg. from the vertical. Proportional lengths should be preserved as far as consistent with speed in the making of gas pipe diagrams. These are generally done on the job, over a rough surface, without any sort of guide except the edge of a pocket-rule to make straight lines by, but the rule is a means of easily limiting the line to conform to a scale or to the scale of the house plans. If the lines are thus to a scale, a forgotten measure,—not set down on the diagram—can sometimes be supplied by means of the line length.

Whether a pipe comes above, below, or between floors, and also the direction of the joists are indicated by the position of an end section, or top and bottom lines dotted in, according to the direction and position as shown in Fig. 472.

Fig. 474 is an oblique projection of the building represented by the floor plots; it, like the floor plots and diagrams, is merely a vehicle for illustrating the method of diagramming. The fixtures are sketched roughly in place in Fig. 474, together with a skeleton of the soil pipe work, which considered with the diagrams and what has been said, should make the production and mission of pipe diagramming quite clear.

On the plumbing diagram it is easy to see that the points marked **DS** are Down Spouts; **WC**, Water Closets; **L**, Lavatories; **B**, Baths; **KS**, Kitchen-sink and **PS**, Pantry-sink, etc. Hence, when estimating, it is not the custom to mark in full any but ambiguous images or openings, say, like **CO** for Clean-out, or, **DrF** for Drinking Fountain, which might be mistaken for a urinal, etc. The number of feet of pipe, combination ferrules, Y's, $\frac{1}{8}$ bends, $\frac{1}{4}$ bends, and their sizes may be quickly and accurately counted up from the diagram. It serves as a guide to the journeymen in getting up the material for the job, and saves time after he gets to the building, as it makes the "thinking" which the estimator has already done unnecessary on the journeyman's part. For estimating purposes alone, the skeleton diagram is seldom carried further than off-hand pencil lining, but frequently, if the job is secured the diagram is gone over with ink preliminary to making such blue prints as may be required.

CHAPTER LXXXVI

Making Solder

Good wipe joints cannot be made quickly nor easily without good solder and there is much good looking made-up stuff in the market that the best of workmen can scarcely manage at all. If one is sure of the source and the quality, ready made solder is, however, a greater convenience now than it would have been when much lead work kept an ever increasing lot of joints, ends and seams accumulating in the shop, which had to be worked up now and then. Shop made solder was formerly almost the only kind used for wiping, and it is still largely used, principally where considerable lead work prevails, and in localities where the supply people handle only such grades as the plumber has found by experience that he cannot use.

Old sheet lead, scraps of pipe, lead ends from joints, and tacks, pig tin, old block tin pipe and tin foil, are all used in solder making. Of these, old joints and their ends that were attached to brass, and tin foil are unsafe for making wiping solder. While such odd material as may be at hand is so used it is generally kept in a separate batch and fined up or tempered down to suit, aside from the regular lot which a pig will make up,—it is the practice to melt down a pig of tin, 100 lb., at a time.

The usual result of making up a pig of tin with pure lead not considering odds and ends of shop stock is: 25 1-lb. bars of pure tin; 10 lbs. 60 per cent. tin and 40 per cent. lead strip solder for the torch; 20 to 25 lb. of $\frac{1}{2}$ and $\frac{1}{2}$ solder for the coppers; 40 to 50 lb. of 40 per cent. tin and 55 per cent. lead solder for fine wiping, and 75 to 100 lb. of 60 per cent. lead and 40 per cent. tin solder for coarse wiping.

Considerable time is often wasted by going at the job in a clumsy way and there are usually as many plans of working as there are journeymen in the shop. As soon as the pig is melted, one will likely pour out 60 1-lb. bars, leaving 40 lb. of tin in the pot, to which he would add 60 lb. of lead and pour off 100 lb. of 40 and 60. Fifty pounds of 45 and 55 would next follow by melting down $22\frac{1}{2}$ bars (pounds) of tin and $27\frac{1}{2}$ lb. of lead,—just half of the percentages necessary for 100 lb. of 45 and 55. Similarly, equal amounts of lead and tin would make 25 lbs. of $\frac{1}{2}$ and $\frac{1}{2}$ bars, and as $\frac{1}{10}$th of the percentages that would make 100 lb. of 60 and 40 is 10 lb., 6 bars of tin and 4 lbs. of lead would be melted and run out to make the 10 lb. of 60 and 40 strip solder. This plan leaves but 19 bars of pure tin instead of the 25 bars intended; the total tin melted in the process is 141 lbs. and the total lead, 104 lb. or 204 lbs. total product.

Another workman would probably figure some beforehand and find that 10, 25, 50 and 85 lbs. of solder are to be produced from the 75 lbs. of tin left after running out 25 1-lb. bars of pure tin. He would then run out 66 1-lb. tin bars, leaving 34 lb. of tin in the pot. He would next lower the tin to a mixture of 40 per cent. tin and 60 per cent. lead. It is evident that to do this, the 34 lb. of tin must be taken to be 40 per cent. of the mixture, which is proven by: $34 \div 85 = 0.4$; 60 per cent. of 85 is then, the amount of lead to add to the tin. $85 \times 0.6 = 51$; $51 = 60$ per cent. of 85; 51 lb. of lead are therefore added to the tin and the 85 lbs. of 40 and 60 solder are molded from it. Proper percentages of tin and lead would, in turn, be melted for the other batches, after which the required 25, 1-lb. bars of tin would be left. The total tin so melted would be 141 lbs.; total lead, 95 lbs.; total product, 195 lbs.

These methods are not sheer guess work, but note the difference between them and the proper way:

First run out the 25 1-lb. bars of tin, then proceed as follows: The desired 10 lbs. of 60 per cent. tin and 40 per cent. lead solder contains the highest percentage of tin of all of the batches to be made, and so requires the least lead per pound of tin to lower (temper) it. All of the metal in the pot (75 lb. of tin) is then, to get the best result in the end, reduced to 60 per cent. tin in order to make the 60 and 40 solder, thus: $\frac{1}{60}$ of 75 equals 1 per cent. of the mixture to be made, and $75 \div 60 = 1.25$ lb. or $\frac{1}{100}$th of the mixture, which, multiplied by $100 = 125$ lbs. in the pot when the tin is lowered to a mixture of 40 per cent. lead. $125—75 = 50$ lbs. of lead needed to reduce the tin. $50 \div 125 = 0.4$, proving the 50 lbs. lead to be 40 per cent. of the mixture. The 10 lbs. of 60 and 40 are then run out, leaving in the pot 115 lbs. of metal containing 60 per cent. of tin. Next,—$115 \times 0.60 = 69$, the pounds of tin left in the pot mixture; $115—69 = 46$ lbs.,—the lead now contained by the 115 lbs. of 60 and 40 mixture in the pot. Twenty-five pounds of $\frac{1}{2}$ and $\frac{1}{2}$ (50 per cent. tin and 50 per cent. lead) is the next solder to be made because it is the highest in per cent. of tin of any of the batches then left to be made. The mixture, already 40 per cent. lead, 46 lb., must now be lowered to 50 per cent. lead. To determine the weight of lead necessary to be added to bring it to 50 and 50 is the next step, thus: 69 lb. of tin are contained; $\frac{1}{50}$ of $69 = 1.38$ or 1 per cent. of the required mixture; $1.38 \times 100 = 138$, the pounds weight of the new mixture; $138—69 = 69$, the total pounds of lead (50 per cent.) for a mixture of 138 lbs. of 50 and 50. Now, as noted above, the 115 lbs. of 60 and 40 which it is proposed to alter already contains 46 lbs. of lead and the total lead required is 69 lb. Therefore $69—46 = 23$, the pounds of lead to be added to bring the total up to 69 lbs. of lead. Twenty-five pounds of 50 and 50 being run out from this, 113 lbs. remain. Fifty pounds of 45 per cent. tin and 55 per cent. lead is the next batch highest in per cent. of tin. Using the last

pot remainder and the new percentages, solving for the next batch of lead to be added, gives: 113×0.50 shows that 56.5 lbs. each, of tin and lead, are contained in the 113 lbs. of metal in the pot; $\frac{1}{45}$ of $56.5 = 1.255$; $1.255 \times 100 = 125.5$, the weight of the mixture to be made; 125.5—56.5 =69, the total pounds of lead in 125.5 lbs. of 45 per cent. tin and 55 per cent. lead mixture. 69—56.5 lbs. of lead already contained in the 113 lbs. of 50 and 60 remaining, leaves 12.5 lbs. of lead to be added before running out the 50 lbs. of 45 and 55, which being poured leaves 75.5 lbs. in the pot. This last pot remainder will be found, solving as before, to contain 34 lbs. of tin and 41.5 lb. of lead. The final mixture required is 40 per cent. tin and 60 per cent. lead. Figuring as before, $75.5 \times 0.45 \div 40 = 85$, proving 85 lbs. to be its weight, of which 51 lb., figuring as before, is shown to be lead, leaving 9.5 lb. of lead to be added to the 41.5 lb. already contained. The result of this method summed up is: 25 lbs. tin bars; 10 lb. 60 tin and 40 lead; 25 lb., 50 and 50; 50 lb., 45 and 55, and 85 lb. of 40 tin and 60 lead. Total tin melted 100 lb.; total lead melted, 95 lb. total product, 195 lb.,—precisely as figured to be in the beginning. The saving is in time and fuel. It costs both to melt metal.

The heat required to melt the metal as above may be approximated thus; for the tin: Tin melts at 446 deg. F. Taking the weather to be 50 deg. temperature to be added equal 396 deg. Counting the degrees as heat units, we have $396 \times 100 = 39600$. The specific heat of tin being 0.056, $0.056 \times 39600 = 2217$ units required to melt the tin, not counting the latent heat of fusion which, for tin, is 25.6; $25.6 \times 100 = 2560$; $2560 + 2217 = 4777$, total to melt the tin.

To melt 95 lbs. of lead at 50 deg.; its fusing temperature is 630 deg.; 630—50 = 580; $580 \times 95 = 55100$; the specific heat of lead being 0.031, $55100 \times .031 = 1708$; the latent heat of fusion for lead, being 9.8, $9.8 \times 95 = .931$; $931 + 1708 = 2639$, the total heat needed to melt the lead,—which, added to 4777, the total for tin, equals 7416 B.t.u. to melt the 195 lb. of metal. To allow for radiation, keeping warm, and working temperature exceeding fusion, the actual heat employed would double to quadruple this, according to circumstances, and yet be a small matter, even if water gas with a value of 300 B.t.u. per cubic foot be used, but the value of lost *time* is another question. Also, haphazard methods may get too much coarse stuff and not leave enough tin to carry it through ordinary usage. Again, if there is occasion to sell some solder, the value is in doubt because the percentages of the ingredients are unknown.

The selling of solder involves the work of fixing prices on mixtures. This is best done by a form of alligation, a familiar proceeding in common arithmetic.

Ignoring the question of profit, if solder is worth 20 cents per pound when lead is worth 5 cents and tin 30 cents per pound in what proportions are the lead and tin? The balance method of alligation shows, as follows:

Lead, . Worth per lb. cts. 5	X	10-lb. Lead at .20 = 2.00 = $1.50 Gain
Solder, " " " " 20		to
Tin, . . " " " " 30		15-lb. Tin at .30 = 4.50 = $1.50 Loss
		25 lb. Solder at .20 = $5.00

The proportions are seen to be 60 per cent. tin and 40 per cent. lead:

It is evident that the tin costs 10 cents more per pound than does solder at 20; 10, the difference, is therefore set opposite the price of lead; lead costs 15 cents less than the solder, so 15 is set opposite the price of tin. These numbers show the proportions of the metals that go to make up the solder at a metal cost of 20 cents per pound and may be considered as pounds. Inspection shows that 10 lbs. of lead are worth $0.50; 15 lbs. of tin, $4.50; both together, $5.00; that the 25 lbs., of metal at $0.20, amount to $5.00; that 10 lbs. of lead sold at $0.20 is a gain of $1.50; that 15 lbs. of tin sold at $0.20 is a loss of $1.50; that the number of cents loss per pound on tin is equal to the pounds of lead that must be sold at the solder price to produce a gain that will balance the loss on the tin; and that the gain in cents per pound on lead sold at the mixture price is equal to the pounds of tin needed to be sold at the evident loss to balance the gain on the given pounds of lead at the advanced price of solder. The transposition of loss and gain to opposite terms thus establishes the ratio of ingredients,—in the case shown, 15 lbs. tin equaling 60 per cent. and 10 lb. lead equaling 40 per cent. of the 25-lb. mixture. The amounts so determined can be multiplied or divided to raise or decrease the aggregate to any figures desired. Similar transpositions will give ratios for mixtures at other prices, whether the ingredients be metals, or other materials.

CHAPTER LXXXVII

Preparing Ends for Wipe Joints

The shape of the initial tapping for branch joints varies with the size of branch and run. On supplies, the wall is thick and the bore small, so the tapping ordinarily varies little from the round. For large waste pipes of equal size the branch opening may be merely a slit with circular eyes at the ends, the whole being twice the turn-up distance less than the diameter of the branch pipe. In branching $\frac{1}{2}$-in. or $\frac{3}{8}$-in. into $\frac{1}{2}$-in. or $\frac{5}{8}$-in. a round hole like **A**, Fig. 475, is made with the tap-borer, and

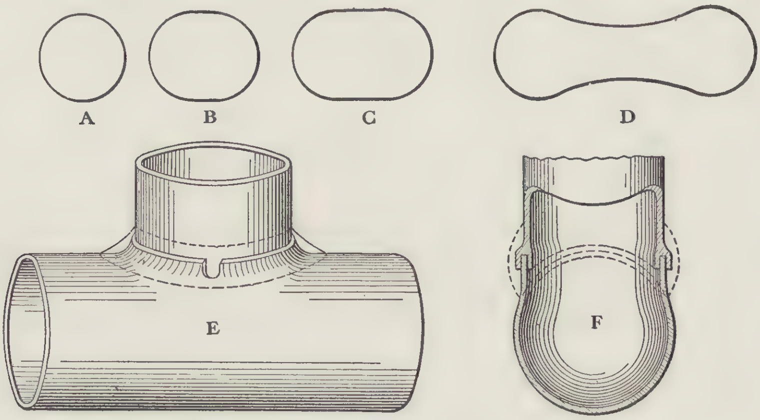


FIG. 475. BRANCH OPENINGS FOR WIPED JOINTS

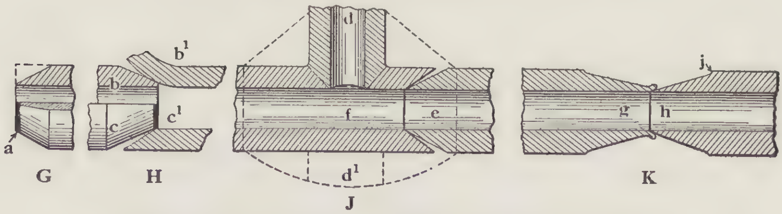


FIG. 476. PREPARING SUPPLY PIPE ENDS FOR WIPED JOINTS

whatever working is necessary is done with the round iron. For branching $\frac{5}{8}$-in. into $\frac{5}{8}$-in. the hole is cut more or less oval as shown at **B**, entering the tap borer at each end of the hole and working the cuts to meet,—some length at the ends, and considerable stock at the sides, being thus left to work back and outward with the round iron. For $1\frac{1}{2}$-in. waste entering $1\frac{1}{2}$-in. the hole may be cut 1-in. long by $\frac{5}{8}$-in. or $\frac{3}{4}$-in. wide. It will then work out to a fairly flat end stock with thin side edges, if the end turn-ups are not carried too high. For $2\frac{1}{2}$-in. entering $2\frac{1}{2}$-in. the

opening would be more like **D**, while for 1-in. entering $2\frac{1}{2}$-in. the hole would be cut practically round. The larger the pipe and the nearer the branch pipe is of the same size as the "run" the greater should be the difference in length and breadth of the hole, as a general rule. In large sizes the stock cannot be worked out to a flat end,—the sides stretch thin in working out and must be trimmed back to stock of reasonable thickness. This lowers the sides of the stock turned up and calls for corresponding long side edges on the branch pipe end that give it and the edges of the branch-hole compensating curves, usually of somewhat greater radius than that of the run pipe, as indicated in sketches **E** and **F**. To prevent the branch pipe from settling down further than intended, under the influence of heat while wiping, and thus interfering with the bore of the run, lips are cut in the side edges of the branch ends of waste and soil and settled over the turned up edge of the run, as shown over **E** and in the sectional view **F**. Lips might also be cut to fall at the length extremities of the hole, but the top of the arch does not resist the thrust of weight so well as the side walls, which, where hottest when wiping are practically straight.

In Fig. 476, is a series of sectional sketches showing ends of supply fitted for different kinds of joints. At **G** is a spigot end, rasped down to about the usual angle,—the upper wall being shown in section and the lower part in general view, with the tip end soiled (**a**) to prevent solder from sweating by. In **H**, **b** corresponds to the section, and **c** to the general view of **G**. The longer bevel on **c** is made to give a solder cup when the receiving end $\mathbf{c}^1$, is merely bored out with a tap-borer (a greater angle with the "run" than **C**). If the receiving end is rasped off on the outside and opened with the turn-pin (tampion) as shown at $\mathbf{b}^1$, it can be given any angle of cup desired, and the usual rasping of the spigot end answers. The funnel of the receiving end should be carefully cleaned and the deepest part of it soiled around. The stop edge soiling of the two ends come together when the joint is set and effectually prevent solder from sweating through into the pipe while wiping. Incidentally it may be stated that the cup space is very important in that its surface alone assures a safe joint if wiped full and hot.

Sketch **J**, shows in section at **d** a branch into **f**, and at **e**, a spigot end entering **f** as for a round joint. On supply the walls are generally thick enough to depend upon the bevel surface of the hole for safe fitting without any decided turning out or working up of the "run" stock. The bevel of both spigot and hole are cleaned and stop soiled as for a round joint,—solder generally sweats in as far as the stop soiling. Though there is little occasion on supply work, some plumbers are strict in opening the end of the pipe which receives the contents unless for an upright joint in which the spigot end is pointed downward regardless, in order to have the cup in the best position. In the case of a com-

bination branch and round joint, as indicated by the sections and dotted line $\mathbf{d}^1$ of **J**, the joining edges of the round joint are thrown much further than shown, away from the end of the joint by thus rasping into a spigot the end containing the branch. Though the spigot entered as shown could be much closer than drawn it is in any event, by reversing, brought nearer to the branch to equal the traverse of the cup bevel. The only difference in appearance between a plain branch and a combination joint is the round back added to the branch in order to include the round joint ends.

A section of the lead as prepared for a so-called secret or invisible supply joint appears at **K**. Such joints are wiped now and then to preserve appearances, where the ends of one pipe of a number must be joined at a point where there is no other joint to match. Whether **g** or **h** is the spigot is of no consequence. An essential to neat work is to shave the edges deep at **j**. The solder should be fine, well patted up, the heat uniform, and the wiping done hot.

Types of Joints

The cloth and copper-bit have made most of the plumber's joints in the past and will continue to do so, though sweated joints on certain service are none the less efficient and will be oftener pressed into service in the future wherever their peculiar fitness is not circumscribed by some untoward conditions. There is a lively prejudice against any but wiped joints on the part of many who have mistaken the cause of the usually good and lengthy service of the wiped variety,—attributing the merit solely to the mode of making. The fact that a joint is wiped and of the usual dimensions is not conclusive evidence of merit. A safe joint can be wiped much smaller than the general run of joints, but not to compare in size with the weight of solder capable of equal service when compacted to the utmost as given by a flowing heat. The ease of wiping, porosity, probable imperfect laps, butting masses too cold to properly weld, uncertainty of perfect tinning,—etc., all combined make it advisable to stick to the dimensions under which the wipe-joint has preserved its reputation.

Supply pipe joints on $\frac{5}{8}$ in. and larger vary from 2 to $2\frac{1}{2}$ in. in length according to the kind of work or style of the workman. For supplies less than $\frac{5}{8}$ in. they vary from 2 in. length for $\frac{1}{2}$ in. to $1\frac{1}{2}$ in. for light $\frac{3}{8}$ in. If several sizes of pipe are used together, the joints are usually made the same length on all for the sake of appearance. Waste pipe joints up to 2 in. diameter range from $1\frac{1}{2}$ in. to $1\frac{1}{4}$ in. for the 2-in. For over 2-in., lengths will be found varying from $1\frac{3}{8}$ in. to 1 in. for 4-in. For diameters over 4 in. the lengths increase some. These lengths, it will be seen, vary roughly with the thickness. In the larger sizes of waste or soil, hot water is not brought into such general contact with the

wall of the pipe, as takes place with the smaller sizes, and the wall of the larger pipes does not average thicker; also, the smaller sizes are often in view in proximity to supply pipe. All these facts have no doubt had influence in molding the practice as to lengths of joints.

In Fig. 477, at **L** is shown a round joint on ½-in. pipe; for comparison of lengths a portion of a joint on 4-in. soil pipe is shown at **P**. A common branch joint is shown by solid line in sketch **M**. The concaved neck is easier to wipe than the swelled neck indicated by the dotted lines and is therefore the usual shape. Sometimes a double-branch

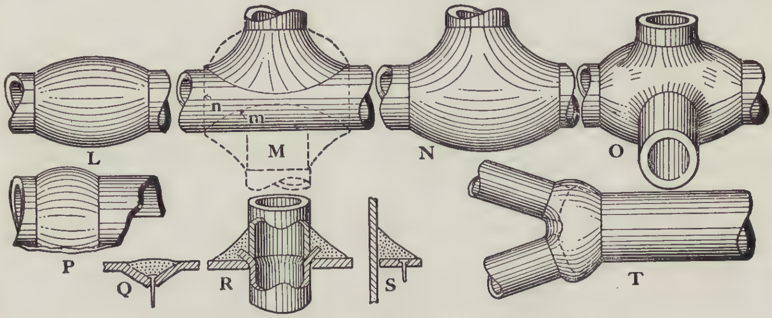


FIG. 477. WIPED JOINTS, FLANGES, SEAMS, ETC.

or cross is wiped like the sketch **M** including the dotted joint **m**. The usual form of cross-joint is with four diametrical edges like shown dotted at **n**; when the cross is given the form of a double branch as indicated by the solid back and the dotted back **m** it looks better, but is difficult to so wipe on account of the opposing backs and is often made by wiping the two branches separately, pasting out the back of the first on both sides by attaching one edge of the paper along the center of the pipe back of the second cleaning.

An angle form of cross-joint is shown at **O**. This style is easier to wipe than the plain cross because there are no more edges to watch, the edges are better situated and there are no big flat areas to keep up. A branch and round joint combined is shown at **N**,—these are handy where both joints come most conveniently at the same point. If the receiving end is to be branched an opening is made to the run near the end and the end opened to receive an end. Unless a distinct annular cup can be given the straight joint ends and they are close to the branch, considerable more than half of the length should be given to the side containing the straight joint. None of these special forms should become a hobby. They are often exceedingly hard to *remake* in place and if there are stop cocks ends so wiped in, it is often not long until the joint must be made over on account of one of the cocks.

Sketch **T** illustrates a form of Y-joint used oftener in electric cable work than in ordinary plumbing. In preparing for it the end of the

main pipe is cut to follow two planes receding from the center at about 45 deg. angle from the diameter. The end is then worked into two oblique circular openings for the branch pipes, the long points being worked over to help form the crotch separating the openings, giving the main end a breech shape like the dotted lines in the sketch. Another form of Y, not illustrated, sometimes used for branch waste pipes, is really nothing more than an awkward looking branch joint, the branch being entered at any angle desired, but rarely more acute to the inflow of the run than 45 deg.

Sketch **Q**, Fig. 477, is a section of flat wiped seam such as is usual for crossing the bottom, or on the walls of a tank, or for crossing a trough or baptistry floor, where drainage over the seam is necessary. The wood support is channeled out for sinking the lead to give the seam the required solder section. The section of a flat seam is much like that of the "invisible" wiped joint, a lead section of which is shown at **K**, Fig. 476. **R** is a broken view showing a section of a common flange joint such as is regular for joining waste, vent and soil pipes at the floor, on walls, or on support blocks. It is proper to cut a sheet lead washer to the size of the joint and pipe, place it over the pipe and swell the receiving end as shown. Flanging the pipe down flat on the washer is not a good way; neither is flanging the pipe to the floor without a lead flange, for the solder will not wipe well on a bare wood edge. **S** is a section of flange wiped on a blind pipe. The lead flange for such can be split on one side, in order to slip it into place. The joints mentioned include all of the wiped class that may be considered at all regular.

The relative size of ends joined, positions in which they must be wiped, local features contingent upon weather, position, solder, etc., make an endless variety of conditions, to be contended with in practice, which pen graphics are wholly inadequate to picture to an advantage worth the while. This is also but too true if alone the operations of joint wiping on the bench are considered.

In Fig. 478 are shown a frost break and a cable splice. Of the splice, **U** is the sleeve, large enough to cover the wire splicing, and **U**^{1} the cables. The sleeve, usually 12 or 15 in. long, bridges the gap between the cables, necessary to splice and insulate the wires one from another. The wire splices are divided over the gap in a way to keep the bundle as small as possible. The sleeve diameter is generally 1 in greater than that of the cables, giving the connecting round joints a flange-joint character. One end of the sleeve is drawn down before slipping over one of the cables and the other after the sleeve is slipped back over the wire splicing to cover the end of the other cable.

At **V** is an untouched frost burst; **V**^{1} shows the swelling dressed in and the break closed by a short lap of the lead, while **V**^{2} illustrates a wiped patch, finishing the repairing. The wiping is not always confined

to a neat patch like shown. The break may be the second almost at the same spot. If, in the judgment of the workman, such is necessary to make a reliable job, there should be no hesitation about wiping a long round joint over the break,—even 6 in. or more in length if necessary.

Referring again more in detail to the manual operations of joint-wiping:—For practice wiping some wood blocks the size of brick with a V-notch in one side should be made. With these a joint cleaning can be set and held firmly by tilting away from the cleaning the blocks supporting the cleaned ends. When the weights to hold the pipe in place are applied the tilted blocks tend to straighten up and thus push the pipe ends together.

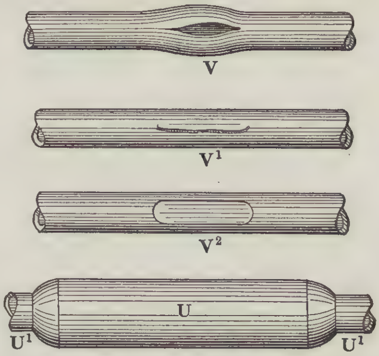


Fig. 478. Bursts in Lead Pipe, and a Cable Splice

The beginner should heed the following: A blind cleaning is best for practice: the pot should be kept heating near at hand, so cold batches can be melted down again in order that pouring off and rewiping may continue without loss of time; a ring of paper 2 or 3 in. wide pasted on each side of the cleaning stands the wear of rewiping better than soil; use the cloth with the left hand, keeping it forward to cover the tips of the fingers; skim, stir thoroughly and reskim the solder before using to get it clean and to mix the tin and lead; do not stir or skim solder until ready to use it; a temperature corresponding to a dull red in twilight is hot enough for the pot mass,—it will scorch a dry clean white pine stick at that heat; a still molten mass of solder stratifies in the pot to some extent, the tin coming to the top, the dross on the surface saves tin by retarding oxidation; the lead stands the higher heat of the bottom of the pot better than the tin would, and what of it is so lost costs less; wiping solder should never be coarser than $\frac{2}{3}$ lead; supply wiping should be $\frac{2}{5}$ tin or finer; the very coarsest solder usable is good only for wiping blind flanges and other supporting joints; the more the tin exceeds 40 per cent. the more difficult the solder is to wipe with; beginners should use a solder of medium fineness; practice only with pure solder; never fine up with $\frac{1}{2}$ and $\frac{1}{2}$, nor stick solder of any kind, nor melt down in the pot old joints with brass ends; do not tin brass in the wiping solder; use only one cloth for any joint in any position until able to wipe any in any position up to 2 in. diameter; use no wiping cloth over 3×3 in.; $2\frac{1}{2}$ in. wide by 3 in. long is the best size, except for flange joints and some branches, for which 2 in. wide is better; large hand-pocketed cloths for getting up a heat on large pipe may be any size desired; use good herring-bone ticking cloths not over 12 double, with the outer layers

only well greased and singed,—ticking is always to be had and can be made up by the plumber; heat brass ends before wiping; wipe both ends of a cock in at once to take advantage of the running heat; use a plumbing iron on large joints to help out, if necessary; a big joint may be wiped in sections like a tank seam; a live charcoal wrapped in screen wire can be placed inside a pipe to help heat up; stopping up ends aids by preventing passage of cold air through the pipe in cold weather; be certain you have *solder* in the ladle before pouring it on a cleaning.

Get the above points fixed in mind, and then remember that an apprentice will progress as well if he is contented to practice only at pouring and dropping solder for a few days, without trying to wipe. It will be found that he can do no better than imitate those who know how and that there is at first no need to try to immediately fathom just why. Experience will soon teach some things that words cannot explain to those without it, and after experience there is little need for explanation. The forming and patting up of rough joints is in order after experience has taught that a few very hot drops on one spot will burn a hole in the pipe; that the size of the drop and the distance it is made to fall are gauged to control the heat of the drop as it reaches the pipe; that a stream of solder of greater or less size may be poured on with impunity when the solder is cool or a mass has been accumulated on the pipe to pour on; that a little passing around of the mass tins the surface of the cleaning and that conduction of heat from well spread masses rapidly laid on as soon as there is a covering to protect the lead heats the pipe more effectively than ordinary dropping or pouring. As forming-up practice proceeds, one will unconsciously begin to flip off a thick edge here and there; to drag off a surplus or pull it over from a full spot to a low place now and then; to quickly stop a bottom chunk from falling off while shaping on another part; to pass the mass around the pipe to get a hot bottom on top where it will not fall,—and thereby find that the cold top apparently gathers heat when placed at the bottom. A well formed rough joint will soon result and the temptation to wipe it will be irresistable.

Presuming a cleaning ready to wipe: Hold the cloth well under the cleaning and drop the solder, drop by drop on the pipe, gauging the speed and size of the drops according to the heat of the solder. Keep the ladle moving along the cleaning and forward and back so as to drop everywhere on it, but not much anywhere at a time. When some accumulates on the cloth, put it up; when this has been done several times hold a soft mass as close up against the bottom as conditions will allow in order to warm the bottom and help break up the fins and stickers protruding downward. When the cloth is loaded, put the solder up and again catch it, close up, while extending the pouring out on the soiling

2 or 3 in. at each edge to warm up the adjoining pipe. This will aid in finishing the joint before the edges get too cold. The edges being thinned down considerable as the joint is rough formed, they require heat in the nearby pipe to feed the edge solder and to check or counteract conduction of the solder heat along the pipe. When there is enough solder hot enough on the pipe and cloth to make the joint after discarding the cold masses which it is evident cannot be further used, and the conduction masses on the pipe have been poured down at the ends of the cleaning, so they can be knocked off, put the mass up. It will run off if allowed, but must be caught with the cloth and brought up again. The coldest of the mass will stay up easily. By holding down one edge of the cloth a rotation can be made that will clean the edge and carry some of the colder solder over the back to the bottom; there the bottom can be pressed up by winding the hand and cloth or fingering the cloth to give the mass a center thickness; the cloth is then brought back with the hand *over* it, pressing on the opposite edge of the mass; at the top a twist is made that drags the end of the cloth over the joint-end and the cloth is backed down, next the person, with the hand *under* it, cleaning the edge and carrying the colder solder over to the bottom. The other edge on the near side is then cut off, down or up, perhaps by a trial wipe. So far the solder at the edges of the cleaning has been left comparatively thick and extending some over the soiling so there will be a wiping heat next the lead when needed. Being sure the mass is so distributed as to make the joint full all around, it is pressed up and the big edges cut off, winding up each pull or edge-wipe with a sudden increase of speed that clears the joint and flicks the surplus out of the way. If the mass is at all lop-sided, say thick at the top and thin on the bottom, a quick full wipe with curved cloth is made to carry down from the top enough to fill out the bottom; if the bottom is heavy, some of its surplus is pulled up or off. The top of a joint, wiped laying down, must be made sure of first. A stiff cloth will hold the curve by pressure at the joint edges with the first and third finger; a soft cloth must be kept from bagging too much by proper support with the middle finger. A joint will become uniform by continuing the full wiping around the pipe and maintaining the desired curve of the cloth, letting the surplus pulled along feed under the cloth to low places instead of flipping it off. Very little width of cloth in excess of the length of joint is best with stiff edged cloths like those made of mole skin,—considerable excess of cloth width is best when the cloth is thin or flexible as those of ticking. The finishing wipes should draw on the whole width of the joint,—one pull being made from well down at the back to entirely over the top, flicking the surplus off; the other, final, commencing under, and lapping the beginning of the previous pull, and carried around to the top, both pulls cutting the edges down to the ends of the cleaning. If the solder is soft

and hot at the end of the final wipe, throw the surplus off and let the marks sweat in; if the solder is stiffening rapidly, stop the cloth gently and pull off the surplus by a length-wise stroke. The foregoing is one way to wipe a horizontal round joint. So far as getting up the heat is concerned there need be little departure from directions for any, but the ways of handling the solder when it is ready to form up are infinite. Some plumbers are the slaves of two cloths for all joints; some rarely use two except on large joints. Two cloths are often very handy in equalizing the heat of a mass, and in shaping where conditions require quick work; also in holding on to the solder when the pipe and cleaning have become too hot. Solder for the bottom of branch joints, laying flat, is sometimes worked down the necks and pressed up—the person being at the back—from the neck side; again, it is wiped off of the top surplus with one cloth on to another and bodily transferred to the bottom.

One should not become a slave to certain positions, by seeking and contriving easy positions from the start. It is best to face the fact that any joint can be wiped in any position and then, from apprenticeship on, let the joint positions fall as they happen, and so wipe them until a master of the art under any conditions that occur in practice,—there will yet be ample time to seek the easy and usually more rapid way of planning a head to let joints fall in advantageous positions. Any apprentice who will thoroughly familiarize himself with what has been said and endeavor to act accordingly need not fear but that he will master the joint wiping end of the business. The means to an end for taking care of other joints of various sizes and positions will suggest themselves in ample time,—he has but to carefully fit the ends, soil well on clean lead, shave the edges deep and the surfaces clean, protect the cleaning with tallow, set the joint firmly, provide for taking care of house finish and for saving his surplus solder; then apply his acquired knowledge with the same earnestness that would characterize his efforts at anything else worth doing.

Plumber's Soil and Soil Substitutes

Book-binders paste, paper pasted on, Irish potato juice and other things are used to prevent solder from sticking, but black soil is most used. A small amount of it can be made by dissolving an ounce of common glue in hot water and adding a pint cup full of loose lamp black. The mixture is then boiled and stirred, to thoroughly mix the glue with the black,—in enough water to make it the consistency of cream. The surface soiled must be cleaned and the soil should always be used hot. If soil rubs off easily, add glue. If there is too much glue it will check and peel, showing that it needs more lamp-black. When of the right

proportions, soil will take a polish if painted hot on clean lead and rubbed with a dry finger after it is dry. New lead can be cleaned by rubbing with chalk.

Copper-Bit and Butted Joints

In sketch **W**, at **a**, Fig. 479, is shown a copper-bit joint of the usual appearance, employed for attaching basin cock couplings, extending short ends on waste, etc., where the wiped form would be unsuited or difficult or impossible because of lack of length. Its principal solder hold is the cup between the end surfaces. Well made, its solder is floated to the full depth. When the swell is slight or the pipe can be tilted to favor, it can be smooth flowed at about the angle of surface shown, by drawing the iron around to produce a continuous flowing heat. At **b**, is a butted sweat joint.

The actual joint so made is scarcely visible. For it, the ends are squared and fluxed; one end is then heavily tinned with a torch and the other stood on it and heated until it settles down evenly. This joint will stand more internal pressure and tensile strain than the pipe and will reduce in diameter without damage under a strain that will stretch the pipe. One pound of solder will make more than 50 such joints on $\frac{5}{8}$-in. supply.

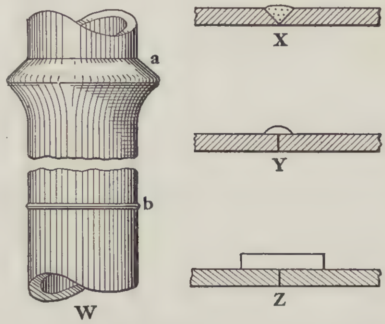


Fig. 479. Copper-Bit and Other Solder Joints

Seams

At **X**, Fig. 479, is shown a section of a copper-bit seam with edges beveled to give a solder section without projection, such as is used for safe pans, floor sheets and bottoms, where a flat finished surface is desired. At **Y** is a section of butted edge seam, such as usual for soil pipe and traps. For this the edges are soiled and then cleaned part of the way down, thus leaving a stop edge of soiling; the surfaces are cleaned, and deep-shaved at the seam edge. The solder sweats down between the edges and builds up in a welt above, as shown.

Fused Lead Seams

At **Z**, Fig. 479, is shown the preparation for welding two lead edges together without solder. The edges and a little adjacent surface of the pieces to be joined, and the whole strip of lead are cleaned and fluxed. For a short seam the strip can be laid down and the seam melted from end to end, shoving the pieces together a little when the edges are melted, if they draw back too much to allow the strip to fill. Thin lead

draws back more than heavy lead because of the extra stock (width) needed to supply the thickness due to cohesion of the molten edges. If it makes little difference about the finished dimensions, the edges can be melted and shoved up to suit without using the strip of lead. The lead strip may be held and fed to the seam as needed, if preferred. If laid down, as shown, the thicker and narrower the strip, up to a square section, the better. An alcohol blast flame (the torch and blow pipe) is needed to fuse the edges. The work is best done on a smooth cast iron surface. One need not be surprised at a profusion of water drops appearing, seeming to come out of the metal from every pore, when beginning a heat in cool weather. The water soon ceases to appear under a continued blast. There are many occasions for using fused seams to advantage, and the little practice required brings the aid within reach of all who care to employ it. The author has welded lead linings for soda water generators in the manner described.

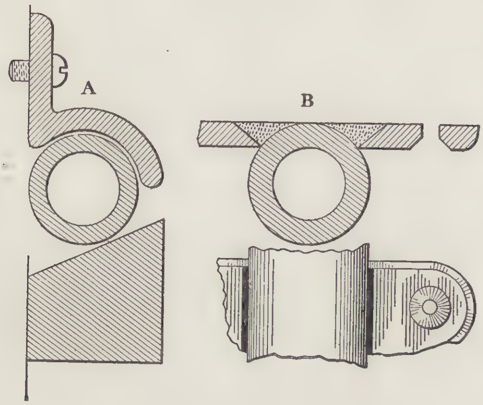


Fig. 480. Tacks for Lead Pipe

Tacks and Support Strips

Lead soil pipe was generally held in upright position by bands, ears tacks or brackets, of sheet lead, surrounding the pipe in strap-fashion, the ends being bent out so screws could be run through into a wall board. They were soldered to the pipe near the back on each side. At the front, the sheet band was cut out to expose the pipe, often in the shape of a cross, spear or shield, and the two parts wiped together.

For small waste and supplies running horizontal or inclined, bevel strips are, where permissible, used below the pipe as shown in sketch **A**, Fig. 480. As top keepers, especially for supply, shelf tacks like shown in section in sketch **A**, were above, but not soldered to the pipe. They were rarely used to support the line, though the name implies support. These tacks, like the common tacks to be soldered on, are hand-molded by the plumber at odd times. The shelf tack often requiring more stiffness in the leaf than pure lead will give, copper-bit joints from brass ends, lead ends from "brass-end" wipe joints, etc., are added to the lead for them, to give stiffness through the tin contained. Common tacks are molded of pure lead, and soldered on, usually in pairs, as indicated in sketch **B, Fig. 480.** The distance apart for tacks soldered on varies,—

for upright pipe, from 12 to 18 in. according to size and weight of pipe; for level runs they are sometimes placed on the lower side only, at intervals of 9 in. or more.

CHAPTER LXXXVIII

Tank and Sink Seam Work

A novice at seam wiping not having seen the work done, oftener than not will attempt the first seam by spitting solder over as much seam length as he thinks the hot solder at hand will heat up for wiping, and too late finds that long reaches of seam cannot be handled that way. Spitting solder from the ladle with a small paddle-like stick, to cover a short stretch, massing it from time to time with the stick or ladle or both and then spitting on more, fresh from the pot, is the proper way and is continued until the mass is soft enough to not damage a cloth. The cloth is then used in place of the spit stick, the solder worked up over the seam and added to from the ladle while being gotten into a mushy semi-fluid mass favorably shaped to wipe along. Rather hard pressing is necessary on the final wipe of any portion of a seam. The mass is cut down to something like seam dimensions by a preliminary pull to get the big surplus forward and out of the way. Then, the cloth is again quickly drawn along the rough stripe, pressing hard enough to force the lead against the wood beneath. This usually requires more than enough pressure to cut the solder down to the edges of the cleaning. It should leave behind the cloth a bright, smooth, well-formed straight-edged seam, provided enough of the heavy pressure has been distributed to the edges of the cleaning where the lead stock would bear it, and not so much pressure left on the center of the cloth as to dig the center of the seam too hollowing. If the solder has so far been dexterously handled, the wiping will be 6 to 8 in. long and the surplus left will be possibly small enough to be again warmed up with fresh solder from the pot so that a second short stretch can be wiped to a finish. In the majority of cases, however, the plumbing iron is put into service following the wiping of the first stretch and the surplus worked down into finished seam until very little of it remains,—the iron furnishing the needed heat, helping to mass the solder, and tinning the seam by its movement.

A plumbing iron is a double cone bolt of iron about 6 in. long and $1\frac{3}{4}$ in. or less diameter in the center, with a swelling taper ending in a blunt point at one end and having the handle attached at an angle of about 40 deg. at the other. It is used, untinned, as illustrated in sketch **D**, Fig. 482, and when first applied should be fairly red hot. Several irons are kept heating in the furnace and when one ceases to be effective from loss of heat, another takes its place. It is the helper's job to have a fresh iron hot and ready when needed. Having the iron ready, means:

it has been pulled from the fire with the eye end of the pot hook and given a swing so the handle can be dropped through the eye until the iron is checked by the ring of the hook. The handle is next submerged in a bucket of cold water until cold up to the iron. The iron is then cleansed by a vigorous raking all over the bulb, with an old file, to remove scales and oxide which might detach and remain in the solder. If not needed instantly the handle is again submerged. When needed it is quickly brushed with a carding cloth, wire brush, or something that will insure it being clean when plunged into the solder. One would

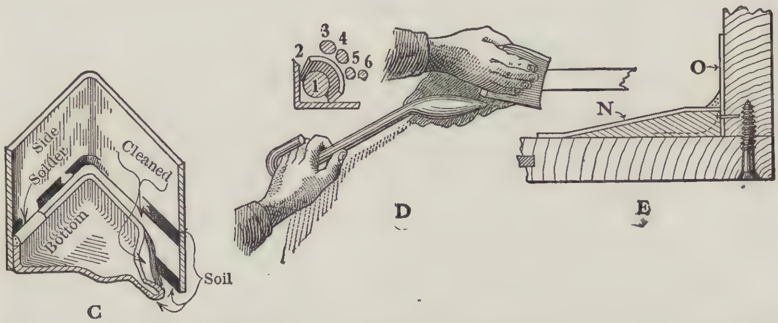


FIG. 482. C—SWEATED IN LININGS. D—USE OF "PLUMBING" IRONS. E—BLOCKING UP FOR A NEW BOTTOM LINING

suppose that much of the heat was lost by conduction in cooling the handle of the iron, but it seems to have little effect. Indeed it is said, and apparently borne out by experiment, that some of the heat in the handle is driven back into iron by cooling the handle.

In sketch **D**, Fig. 482 the left hand is shown holding the iron in position to soften the surplus so it can be pressed up and worked along the seam in a bank. This banking far exceeds the requirements of the seam. The cloth and iron are both used in so manipulating the mass,—getting it welding hot into the cleaning, and mushy all along the stretch.

The nose of the iron is then run up to and melted into the end of the finished portion of the seam and with the cloth covering the seam and practically over the nose of the iron, like shown by the small section in sketch **D**, both are drawn along together as far as the solder holds out. A second finishing wipe of the stretch is then quickly made,—even a third or fourth pull may be made over part of the stretch but nothing is accomplished at any point that has hardened. In the small section, **1** is the iron, **2** the cloth, **3** the index finger and **6**, the little finger,—these being about the positions for the rough pull which follows up the iron. Some men like a very narrow cloth; others one $2\frac{1}{2}$ in. wide or so. If the cloth is of liberal width, the edges will curve with the lead walls on the rough pull; in any case, the curve of the body, on the finishing wipes, is reversed from that shown in the small sketch.

Whatever the length of the seam, the actions already described are repeated in more or less regular order until a meeting point is reached. Sometimes the finished section of seam at the beginning point is pasted over with paper, at others, the finish to be joined is covered by rubbing on common chalk. Paper is not as easy to heat up to, but is less likely to cause other trouble. One does not dare to freely rub hot solder over the chalked part of the seam. An ample volume of flowing hot solder may be caused to envelop the finish to be met, and the nose of the iron can be traveled right up into the finished end, but no unnecessary rubbing or passing should be done. When the final stretch is ready, pull the big surplus off and out on the soil or far enough back over the seam to allow wiping over the finishing point. When the seam is done, the chalk between the left-over mass and the finished seam will allow the loose solder to be lifted in a mass.

If there are vertical seams in the job, they should be wiped first. There are two practical schemes for disposing of the foot of a vertical seam: one is to finish the upright part down to the foot and there end it abruptly a little above the bottom, as may be done by fitting a thin board in the corner, wiping down to it and removing it while the mass in the way will break; the other is to wipe the upright to a finish and divide it as shown in sketch **B**, Fig. 483. The right hand branch of the bottom seam is ended abruptly by pasting over and weighting a 3-cornered strip or block in the cleaning to wipe over, thus leaving the seam end, as shown in sketch **B**, at the right, or, by fitting a bent paste board in the angle and lifting it with the surplus while the finished wiping is soft enough to break at the edge, as indicated at the left in **B**. One end of the branch of the divided seam is continued until it meets a branch of the next corner. This plan makes for a tank or sink, three beginnings, at, and four meetings with cold ends, as all the verticals would be wiped down and divided before finishing any bottom seam. When the verticals are stopped without dividing, three of them are so done, and the fourth is divided as described and continued around from the right or left branch, thus crossing and joining to three cold upright ends and one meeting. The uprights should be pasted up above the seam height, as there is usually too much work over the new wiping to depend upon chalking up the corners. Wiping vertical seams is in early experiences, the dreaded portion of tank wiping. On shallow sinks, wiped in position, an upright can be handled at one stretch, sometimes, even to dividing the corner, without the aid of a plumbing iron, but it is best to not begin unprepared. The soiling should be liberal,—3 or 4-in. wide on each side of the seams. Some protection may be given the bottom by covering with heavy paper and weighting in all along the seams, especially if the depth is considerable. The solder can be spitted on a short seam and raked up over the stretch with the spit stick until

the drifting gets too profuse; then the cloth does better, as it is more effective in pulling up the mass and can also be used as a target to drift fresh solder into the clinging chunks. Sometimes a good stretch can be wiped at the beginning, by first shooting the back of the ladle down a well distributed mass that has been raised to wiping heat in order to prepare the road for the cloth, and then wiping either upward or downward, to a finish at one or two wipes.

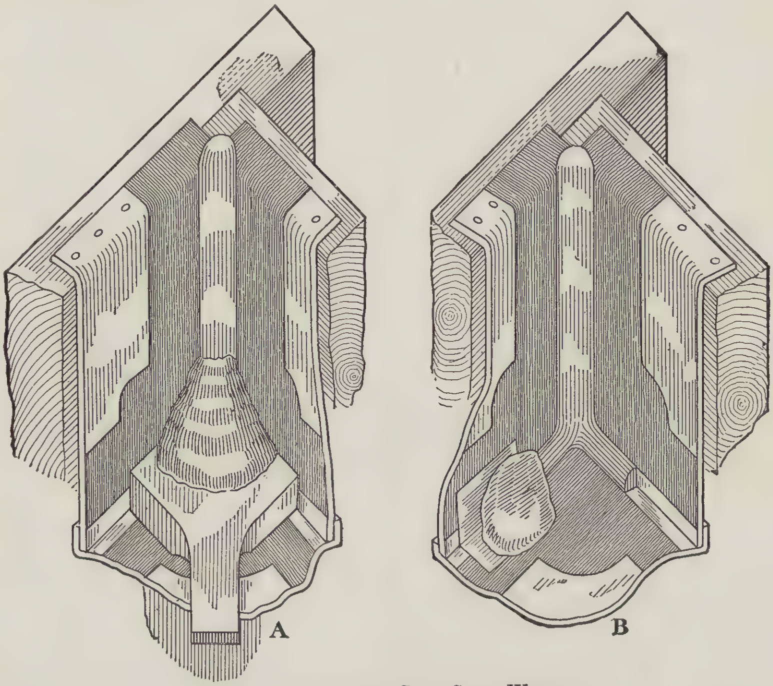


FIG. 483. TANK AND SINK SEAM WIPING

If there is much depth, a corner board something like shown in sketch Fig. 483, is used to stop the droppings and as a bed on which to accumulate the hot surplus, so it can be used as a working mass. If a big surplus has been accumulated on the board in wiping the first stretch, it can be softened with an iron and the board gradually lowered by a helper, while the plumber works it into and distributes it over the seam angle. The cloth can then follow the iron up the stretch, on a trip made to create a wiping heat, winding up with a good hot roll welling up on the lower end of the finished stretch; then the second stretch can be wiped, downward, to a finish. Spitting on fresh solder, as in the beginning will be necessary for the third short stretch. When the bottom is near it can serve in place of the corner-board, if the upright seam is to be divided. If it is to stop short, a thin board or even a piece of paste board can be laid in until the vertical is wiped down,—

the surplus is then returned to a pot. If the vertical is to be divided, the surplus is kept as small as convenient; less fresh solder is then needed to branch the seam and the mass is easily brought to a good heat with an iron. In sketches **A** and **B** the bottom is shown flanged up. This is the way for a wiped bottom angle seam if flanging is done but it is not necessary if the bottom lead is correctly measured and cut with allowance for possible inequalities of length and breadth, obtuseness and acuteness of corners, etc.

The precise shape of a bottom is best found by striking in the tank and on the lead two nominal center-lines perpendicular to each other, and then setting off on the lead, at corresponding points, the actual measures shown by the tank bottom as taken from its center-lines to the walls.

The author prefers to do any seam tacking of the lining thought necessary always in the direction of the walls. Inevitable sag of the side lining will give slack in the wall, and every consistent means of travel should be left open to the bottom. It will be remembered that a bottom is often fitted in at 80 deg. or more; that the first filling of the tank will lower its temperature to the neighborhood of 50 deg. and that in winter it may fall below 35 deg. The F. deg. expansion of lead is 0.00001571; for the range indicated, 45 deg., the linear co-efficient may be taken as 0.00071 of the unit length. Even though this is a small fraction of an inch on a 4 or 6-ft. tank, it is not to be neglected, for the action is, to a greater or less degree, repeated by the seasons and also every time the tank is filled in summer with cold water after the supply in the tank has reached a low level and had time to warm up.

Wall and bottom seams away from the angles are avoided where possible,—they add to the work to be done; are unsightly when wiped crowned over a flat casing surface, and if channeled, as they invariably are, they weaken the casing, especially when the seam is in the side wall. In the bottom, an open V-channel made for the cleaned edges, so that the seam can be wiped flat, effects the strength of the wood but little.

In the past generation not a few tank linings have been seamed like shown in sketch **C**, Fig. 482. Such seams, well made, after a quarter of a century of continuous use in house tank cold water storage show no defect and have needed no repairs,—in fact, have, for several reasons, proven more reliable than wiped seams. First, solder-united surfaces equal in extent to the section of the lead joined are, as is well known, much stronger under tension and will sustain more hydraulic pressure than the lead,—the solder-united surface of the seam shown is easily, as normally made, treble the lead section; second, there is not a rigid line at each side of every seam. Solder alone gives great resistance to contraction, and any seam tacking with brads directly adds to the resistance. In the lining shown, if the side wall is taken to be tacked tight to the

side wood at the bottom edge of the lead (neither necessary nor practised) the lead can still pull away from the wood considerable without damage and as there is no solder in the angle, it will open without harm, giving, altogether, something like a $\frac{1}{2}$-in. play for contraction on each side,—more than needed for a long period of such service, notwithstanding that lead does not again assume its original dimensions when altered by a change of temperature.

For unwiped seams the side lining is placed first, soiled and cleaned at the bottom, as indicated. Seams are not placed in the upright corners, as for wiping, but are lap-jointed anywhere convenient or necessary on the side or end walls. Unless the tank is very large the side lining can be joined out of place and afterward squared up in the tank. The side seams may lap $\frac{1}{2}$-in. and the solder sweated in until it "takes" across the cleaning to the soiled stop edge. If there is not a soil stop edge on the under lap and upper lap is cleaned back to soil, solder may sweat through and form annoying swells or beads on the under side. The upper *edge* should be cleaned and the side cleaning of the under lap should extend out in view a little before soldering. The *working* side of the seam should show in the tank,—a point not to be overlooked, when joining seams out of place. It is best to hold the lead in a straight line by means of an iron bar when sweating in the solder. If an upright seam is being made in place the bar can be braced up from the opposite side or end of the tank. A light piece of angle iron will answer for the straight edge. Its edge should be kept back $\frac{1}{4}$-in. from the seam edge. There need be no worry about the little heat it will take up from the lead,—the specific heat of iron is only 0.1138 that of water and the soiling reduces conduction.

For the bottom, the precise dimensions and snape of the tank between side linings is found and the bottom cut out $\frac{3}{4}$-in. larger all around; full $\frac{3}{4}$-in. is then turned up all around, working the corners up *solid*, and soiled and cleaned on the back and edge, all about as shown in sketch **C**, Fig. 482. The turned up edge is then bent inward at two points and the ends folded over so as to leave room to stand in the tank when the lead is laid in the center. The bottom is first pulled to agree with *locating* marks so it will unfold properly and the ends then laid back on the tank bottom. Then it should be necessary only to dress the turned up edge against the side lining to make it ready for soldering. Fine strip solder (55 to 60 per cent. tin) is used in the seams which are made with a torch and blow pipe. A common gasoline blast torch is too violent and the flame too dirty to give satisfaction. It is best to use wood or denatured alcohol in the plumber's torch. The blast can be furnished with a mouth blow-pipe, or through a hose connecting to a blow tip attached to the torch, though it is much easier to furnish the air with a proving pump, using a closet air-tight tank for air storage.

The solder used is about $\frac{1}{7}$ that necessary for wiping the same length of seam.

The most serious repair job needed for a lead lining, rarely called for, is a new bottom, sometimes made necessary by the lead stretching and tearing along wiped seams. It may be put in as just described or wiped in, as the workman prefers. The old bottom, if wiped in, is removed by cutting loose above the seam; if sweated in, it can, if desired, be cut at or near the bottom, thus leaving the old seam in, as indicated in sketch **E**, in which **N** is the new bottom and **O** the old lead side lining. A strip $\frac{3}{4}$ or $\frac{7}{8}$-in. thick, beveled down to a feather on one edge is then, for wiping, mitered and nailed in against the side walls around the tank. This strip is shown in section in the sketch. Its purpose is to raise the new bottom up to where the old lead can be joined to,—incidentally it holds the new lead away from the old tank bottom boards which it is fair to assume are water-soaked and would so cause steam to interfere with wiping if the new lead was laid directly on the old wood. If the new bottom is to be sweated in, the feathered strip can be dispensed with if the tank wood is reasonably dry, for the new bottom can be turned up high enough all around to make a seam above the old one whether the old bottom was wiped or sweated in.

CHAPTER LXXXIX

Working Lead Bends

It is beyond the power of mere words and lines to convey more than a brief outline of what takes place in making a trap bend by hand either with or without a form. The full knowledge necessary to successful execution can be gained only by experience. Every pointer now picked up, from whatever source, as to how to proceed to work lead into desired shapes seems to have a double value because there is not now as formerly an endless variety of examples in progress either to work on or observe from. In earlier days men were to be found who could work a single piece of sheet lead into a seamless bath-tub lining, and every shop had at least one man who could work sheet lead into tightly tied round pipe pressure-tight knots, as well as do other stunts requiring skill in the manipulation of lead and solder. Such skill is not in demand today, but the ability to work a bend, make an offset, or close an end was never more appreciated.

Trap-beating embraced all the skill necessary to the working of lead into any shape required in the business. The following relative to it will therefore be of general service in the little hand work now required of the plumber. In making a trap, the first step was to form two half pipes, like shown in No. 1, Fig. 485, long enough to equal the neck and belly lines, **a**-**c**, sketch No. 2, from end to end. The pieces were then flattened to sheet form at two points and next bent to trap position, reversing the trough at one point, to approximate the radius of the neck bend, and cupping with the trough at the other to follow the belly of the opposite bend. At this stage, looking across the spread of the trap, the piece looked as shown by the solid lines in No. 2, in which **a,** dotted line, represents the contour of the neck to be produced by sinking the flat into pipe form with the bossing stick; **b**, the seam edge line to which the lead is to be stretched on each side to complete the semicircle of the neck; **c**, the outline of finished belly, back to which the stock is to be dummied in form, and **d** the belly seam edge to which the stock will have to be "worked" (thickened) over to on each side to complete the half trap curve from seam to seam. Sinking the stock at **a**, makes less stretching of the seam edge **b** necessary, and therefore leaves the stock thicker at the seam edge than it would be if stretched forward for the whole semicircle. In the same fashion, dummying the belly stock toward **c** reduces the "working" necessary to reach line **d**,—a point worth bearing in mind, for working the flat stock over to the seam edge of the belly

means reducing the length of this portion of the edge of the stock by thickening it.

In No. 3, $\mathbf{a}^1$ shows the neck bend sunk to contour; $\mathbf{b}^1$, the stock stretched forward toward the seam edge from its original position indicated by the left dotted line; $\mathbf{c}^1$, the belly roughly dummied back, but not completed to contour or rounded up; $\mathbf{d}^1$, the seam edge of belly worked forward and indicating the wrinkles which persist in forming when shortening an edge by thickening it. If these wrinkles are allowed to get too pronounced they are either very difficult to heat out or else cannot be altogether gotten rid of at all. When working without a trap form, various tools can be pressed into service as necessary, to furnish inside resistance here and there in lieu of the form aid. Holding one bossing stick, hardy like, against an inner convex and working down the two adjacent ridges outside with another or the back of the dresser is a good plan. If the stock is thick or in an obstreperous condition, apply a little heat,—this will make it easier to work the lead back into itself. The wrinkles must be prevented or kept in abeyance, so it is well not to dress the stock too much forward at once, if wrinkles appear, before stopping to straighten the wall. Always work a wrinkle out by working toward the seam edge,—little progress is made with the curve by dressing it outward. By careful work, the edge of a belly can be carried over almost without a suggestion of a wrinkle. A good clear white pine stick of oval section with weight and curves to suit the size of work in hand, such as one can whittle out to his fancy with a pocket knife, is almost indispensable in bend making whether the stock being worked is drawn pipe or sheet lead.

No. 4, Fig. 485 shows a completed half for the trap illustrated in No. 5; $\mathbf{a}^2$ has been smoothed by dressing the neck with a white pine dresser while the stock was held on the mandrel, at the same time, carrying $\mathbf{b}^2$ over to the seam edge line from former dotted line position; $\mathbf{c}^2$ has been dummied back to full contour and dressed up smooth,—the final dressing of the belly is sometimes done over a lead form, made by pouring a chunk of lead into a soiled finished belly. This is held against the inner side while dressing the outer surface. $\mathbf{d}^2$ shows the seam edge worked to position, it having been carried over from the position shown in solid line in No. 3 and indicated by the waved dotted line in No. 4. The second half of the trap, a counterpart of the first, is then made to match in the same way. $\mathbf{a}^2$ and $\mathbf{c}^2$, No. 4, correspond to $\mathbf{a}^3$ and $\mathbf{c}^3$ No. 5. Of the second half, $\mathbf{b}^2$ would fit into $\mathbf{c}^3$ and $\mathbf{d}^2$ over $\mathbf{a}^3$.

Hand made traps and seam bends are often left with a slightly oval section, as shown in No. 6, with the idea of saving labor,—there being thus a little less depth to produce in each half. Working a seam bend is similar to trap work. If made from straight strips, as usual, the seams come on the sides as in the ordinary trap. If curved strips of stock

cut to the radius of the bend are used, as is rarely done, the seams come in the neck and on the belly. Made this way, a better surface is presented to the flow when the bend changes the course in a horizontal "run," as the seam is not in the bottom. The thrust of the contents is then also, as usual, against thickened stock, for in any style of working it is the stock of the neck half seam edges that must be stretched,—to approximate the increase of seam line length over minimum neck length.

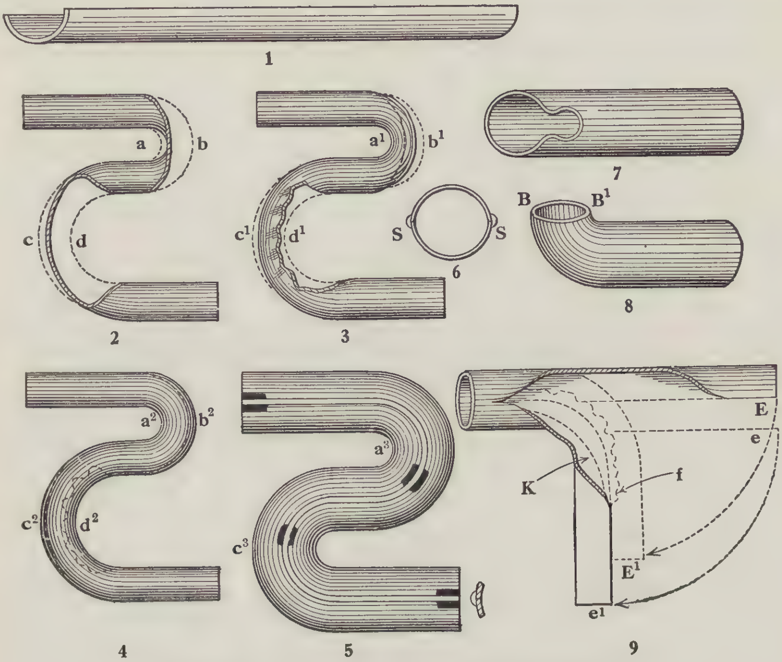


Fig. 485. Trap "Beating" and Bend Making

To work a short bend on drawn pipe, cut out the end somewhat as shown in No. 7, in order to give an unhampered back length of stock for working up the back of the bend. Roughly, the shortening of the neck wall by this cutting should be equal to the pipe diameter, one diameter being a safe distance to cut back on any size. The shape of the preliminary cut is not so essential, as trimming will have to be done, but if the sides prove to have surplus stock by getting far ahead as the bend is worked up, that which is certain to be in excess may be cut off or at least reduced, as it makes the drawing of the back harder, courts puckering and tends to unduly thicken the back, unless very skillfully handled, by resisting the drift of lead in the wall toward what will ordinarily be found to be the thinnest parts of the finished work,—the portions to the right and left of the neck.

Some idea of the proper shape of the end cutting, and why, will be

gained by reflecting on the theory that meridians drawn on the pipe on the bend portion, taking the edge of the cut as one limit and a line across the pipe for the other, would form up into corresponding arcs on the bend surface. From a diameter marking the bend limit on the pipe, the length of such meridians, taken to a proper end cut, should, therefore, agree with the length of corresponding arcs in the bend. This is in a measure correct so far as measurements on the finished bend go, but such meridians drawn on the pipe do not preserve their length, and drift more or less according to the working.

Some men prefer to retain and work against a side surplus. The side surplus works up because it is the line of least resistance; if cut off, as above stated, the resistance is removed and the road is open to more surplus from the same source; if the surplus is left temporarily it forms a bridge wall under which some of the back stock can be forced toward or to the parts that must be stretched into form, and less surplus is thus ultimately trimmed from the sides. Much of the so-called surplus usually trimmed from a theoretically correct cutting is removed at the expense of thickness at some point or other.

No. 8 shows a finished bend, trimmed flat on the end. The higher $\mathbf{B}^1$ is raised the thinner the neck stock will be. The greatest thickness is usually at **B**.

It is sometimes an advantage to work a bend on large drawn pipe,—one with more end than can be knuckled up. This can be done by splitting opposite sides to the required distance, flattening the walls as for a trap bend, and bending as shown and indicated in No. 9, in which **e** comes to $\mathbf{e}^1$, and **E** to $\mathbf{E}^1$,—**K** indicating the neck seam edge partly worked over before sinking the neck, and **f** the back edge partially cupped. The true seam line is dotted between **K** and **f**. The working is similar to that of a trap bend, but very unhandy and no one without experience in common bend work should try it, for no kind of bend making is so easily done as talking about it.

Bends remote from the ends of pipe, would, of course, be worked or wiped in on seam pipe. For drawn pipe some kind of filling is generally necessary on large sizes. Springs are impracticable on large sizes and usually stretch the back of the bend abnormally on any size. Rosin filling melted in, as used on copper pipe, is entirely too hard and brittle. Water is used successfully by capping one end and using a stop cock on the other to retain it. The water is generally used (put in) warm and may be reheated with a torch after filling. The water cools by loss of heat through the walls of the pipe. Its loss of volume resulting must be kept up to some extent, either by refilling through the cock or reheating through the pipe wall. Theoretically cold water would maintain the cubic capacity of the pipe absolutely, as would warm water if the temperature remained constant; practically, there is some reduction

of the pipe, either by the neck stock condensing, or the back "chording" instead of keeping the arc. Whether water is added, because there is heat enough or heat applied to raise the volume, depends upon circumstances. Water is more satisfactory on heavy than on light pipe. Fine dry hot sand, retained by long tapering drift plugs is frequently used on bend making. It is more convenient than water, can be added to easily when it packs and is easy to remove when finished with, or to reheat or to substitute hotter sand, and at the same time heat can be applied to the exterior of the pipe at will. There is one marked difference between using sand and water. Hot water heats the whole length of pipe; cold sand can be tamped in below and above hot sand located to suit.

No plumber now keeps at hand a lot of dummies, balls, bobbins, rams, and other tools once familiar to the trade as essentials in bend making when such was necessarily practised extensively.

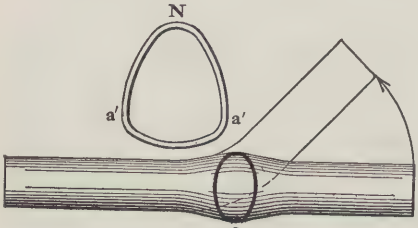


Fig. 486. Bending Lead Waste

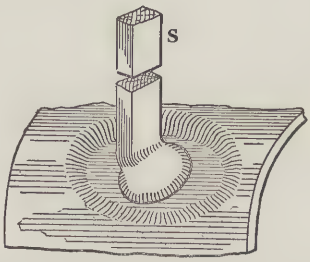


Fig. 487. Pulling Out a Kink

Up to 2-in. diameter very creditable bends can be made without any kind of filling, though not so short and neat on the larger sizes as can be made *with* filling.

The first step is to flatten the pipe along where the bend is required, using a white pine hand-made dresser, and bringing the section of the pipe to an egg-oval,—a little shorter radius in what is to be the neck or throat of the bend than the radius of the curve for the back, as shown at section **a**, Fig. 486. The next step is to bend the pipe, along the oval part, in the direction of the neck, being careful to distribute the bend over the length intended for it and to not bend it too far at once. A little heat applied at the back and neck will help. After warming, the strain of bending must be closely watched on the back and in the throat, for if too warm, the back will show evidence of stretching apart if the strain is continued, while the neck (at **N**) may suddenly begin to wrinkle up transversely. When bending the oval will make an effort to round up to the original form. Before the bend assumes quite the pronounced flat back section shown in the sectional sketch in Fig. 486, it must be dressed up in to the oval shape again, working principally on the ridges

a^1a^1. If not held to the angle bent to the bend will straighten considerably while dressing it. As the bend approaches the desired curve, the oval can be left nearer a circle when dressing it for further bending. When rounded up at the finish the bend portion will be found somewhat reduced in diameter because the length has been increased.

A dent in a pipe or trap not in service can generally be easily dummied out from the inside, but occasionally a dent or flat requires pulling out of a piece the interior of which is not accessible. This is best done by pulling out on a strip of solder attached to the dent as shown in Fig. 487. Warming of the more acute angles of the dent may be necessary. It may also be expedient to attach more than one strip of solder, all according to the character of the dent.

CHAPTER XC

When Plumbing Was Plumbing

Many now working at the trade do not realize how nearly the plumber of a generation back came to being both the manufacturing and the installing end of the business. The last "all lead" job, a country residence, put by the author, a little less than thirty years ago, is one of the youngest of its class and will serve to exhibit the vast changes since made from what might, up to that period, have been called regular practice, though at that time iron soil pipe was in very general use and drawn lead pipe and traps of all sizes were available anywhere, though sometimes by long haul, as were sinks, range boilers and sewer pipe, and everywhere the time when plumbing could be truly termed plumbing indeed as well as in name was rapidly passing.

MATERIAL SHIPPED TO THE JOB ILLUSTRATED BY FIGS. 490 TO 496.

1 Pan closet, body and bowl.
1 Marble stand slab and back.
1 14-in. Round bowl with horn overflow.
1 Copperlined bath tub.
1 Brass plug and stopper for bath.
1 Wall cooking range with cast water-back and 2 brazed copper connecting pipes.
1 16-in. 5-ft. brazed copper shell } body and heads of storage tank.
2 Loose Raised Copper discs }
1 Set brass boiler couplings with lead pipe spuds and tail-pieces.
1 Flat iron ring and bar,—bar to cross corner under kitchen storage tank.
1 Copper delivery tube for storage tank.
1 Roll 6-lb. sheet lead.
Coils of $1\frac{1}{4}$-in. light Lead Pipe, for pump suction and delivery.
Coils of $\frac{3}{4}$-in. medium Lead pipe for house lines.
Lead tubing; Block tin; 200 lb. solder.
2 Cistern valves and stems.
2 Brass strainers; 1 scrap sheet brass.
3 Gross flat head G.P. Screws.
2 Doz. silver covered R.H. Screws.
4 2-in. Wood screws; 1-piece brass gauze.
Stop cocks; faucets, putty; charcoal.
1 Box copper nails; copper wire.
8 Bell cranks; 1 2-in. Pulley.
5 Barrels Q.S. Hydraulic Cement.

FIXTURES AND PARTS MADE ON THE JOB.

Attic Storage Tank, Lead-lined, wood case.
Sewer pipe, Soil pipe, Vent pipe.
Water Closet seat and drip-tray.
Bath tub paneled casing.
Storage tank-heads and spuds wiped in.
Slop sink, Lead-lined, wood case.
Kitchen sink, Lead-lined, wood case.

Today, every fixture and part needed is purchased ready to connect or fit into the job. Then, as shown by the bill of material given above for the job mentioned, some of the important fixtures of nearly every house

with plumbing were made outright on the job, while others were assembled, in addition to making the soil pipe and traps by hand, and frequently drawing down from larger sizes, by aid of a drawing plate, generally at hand for the purpose, numerous odd pieces of small supply and tubing needed.

Fig. 490 shows a sketch of the bath room "roughing in" resting on an unlined floor over the pantry and about three feet below the bath room floor. The roughing in space was reached through a trap in the floor of the slop-sink room. The fixtures were disposed as shown in the plan view above the "roughing in" sketch.

In order to preserve a faithful view of this particular old time job an attempt was made to photograph the "roughing in" some years ago but the space was too small for the lens and the free-hand sketch was made instead.

K is a $4\frac{1}{4}$-in. stack, being a vent from **K** up. It is block-supported, throughout, and therefore stands enough away from the wall to allow wiping the flange joints on the blocks. Stack lengths were joined at these flanges, and two blocks with blind joints wiped on lead flanges were placed between the ends of each length, giving about 30-in. between supports. This is a better method than that of supporting the stack by sheet lead tacks soldered or wiped on and screwed to a board behind the stack, even though the tacks surround the stack and are soldered to it front and back. **M** is a receiving manifold for the branch lines. It is supported by sheet lead knees **NN**, flange-wiped on. A square flange knee is wiped over it near the discharge end and another, a knee and cap combined, closes the receiving end. The knee feet are screwed to the floor. The capped end receives the waste from bath and wash-stand through a regularly made hand-made bend and trap flange wiped to it concentric with the manifold, the one trap answering for two fixtures. **C** is the bath waste, $\mathbf{C}^1$ its overflow, and **D** the stand waste. There is an offset in the stand waste above the floor, hid by the cabinet work which boxes in the space under the slab. **A** is the closet trap and **B** the slop-sink trap. Both these traps have "wiped" bottoms, indicated by **L**. The strengthening of the slop-sink trap was done because the trap space was accessible from the fixture,—the sink strainer being screwed down by two short bolts run into nuts countersunk and sweated into the sink lining. The swinging pan of closet made its trap instantly accessible by lifting the pull. People were thus led to prompt plunging and punching below the pan with mops, broom handles, etc., when choking occurred and unless stiffened by wiping over with solder, closet traps were thus most certain to be punched through in a short time, and such reinforcing of the bottom as shown became a habit.

It will be noticed that the style of venting does not greatly differ from the practice of today. The branch vent line is held up, and kept

from sagging the crowns of the traps, by lead tacks, **H**, wired to the floor overhead. The crown vent line **G** is not a two-seam pipe as might be inferred from the bend on the end,—the bend portion has two seams and the straight pipe but one. The lead for the straight length was split in the center along the bend length and the neck half of the bend formed after the straight part had been half formed on the mandrel; the back of the bend was worked with the full seam edges spread about 60 deg., by

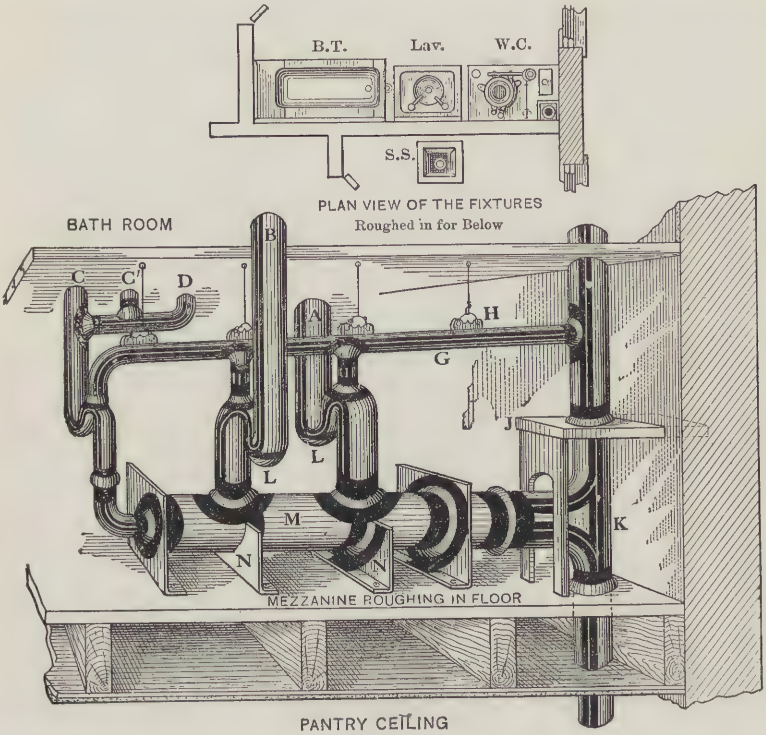


FIG. 490. WHEN "PLUMBING" WAS PLUMBING—A JOB OF ALL LEAD "ROUGHING IN".

reverse bending along the opposite side, finally closing and soldering both sides of the bend, the seam shown continuing to the end of the length. The pipe and bend **D**, and the bend on the end of trap **C** have two seams and were worked in halves and set together the same as a trap. **J** is a two-legged stilt under the support block. The other blocks of the job were made to serve as a frame work to which to attach the wood casing or boxes concealing the stack and were thus supported at the projecting ends by the casing.

The manifold was 6 in. diameter There was no special reason for making it larger than the stack, and in this instance was merely a perpetuation of the style of the man whom the author served his time under. The knee supports never gave trouble, though it is certain

that a manifold of less diameter and of the same weight of lead would be firmer and last longer without signs of settling. Having the manifold larger than the stack required gussets in the stack branch in order to have the circumference of the branch equal that of the manifold. Making the branch as shown gave the advantage of a very high throat. An open throat is obtained where manifold and stack are the same size, by working the branch somewhat as shown, or, by cutting the gussets integral with the back half and thus having no straight seam in the "run" of the branch.

Frequently, in those days, no trap screws were placed in any of the traps. Sometimes the whole "roughing-in" was packed in sawdust, wool, cotton or moss, or the work frost-proofed with boxing. Common salt was dropped into traps to protect the seal during cold snaps. For a season of non-use such as vacating the house for the winter, the seal-water was soaked out or evaporated and the openings closed or the water replaced with glycerine.

The sketches in Fig. 491 give an idea of the hot water storage tank work. The copper shell (with a brazed side seam and side opening spud brazed in), heads, couplings and delivery pipe came to the job as separate pieces, leaving to the journeyman the work of boring holes, tinning edges and ends and, wiping together to suit himself.

The upper sketch, No. 1 of Fig. 491 shows the pipe holes drilled and tinned, the copper delivery pipe (its syphon hole is indicated by **SH**) flanged, tinned and hanging in place in the center hole, and the bent cold water spud seated in the delivery pipe so that one flange joint fixed the hot water spud, as indicated in sketch No. 2. These joints were wiped after the head was wiped in. In No. 1, the head, with joint-edges tinned, is shown setting down in the flaring end of the cylinder, ready to wipe.

The wiping in of a 16-in. tank head is not difficult,—is in fact easier to many than would be that of wiping 4-ft. of tank or sink lead-lining seam, because there is no danger of over heating the copper. Now, a blast torch would be used to warm up the shell; then, a ring fire of charcoal around the shell below the end, held up by knock-down props, was employed. Aside from this no precaution was necessary, beyond having plenty of hot wiping solder, and, for such large heads, two or three hot plumbing irons. A continuous heat permitting the whole ring of a large head to be wiped at once cannot be secured without an unusual amount of hot solder, for the conditions do not favor effective catching of the surplus, reheating, pouring through mushy masses, etc., as may be done to great advantage on large copper-pipe round and branch joints. No. 2 shows the upper head wiped in. Putting in the lower head is simpler as there is but one spud and no delivery pipe. Some care is taken to wipe the surface of the lower joint rather flat to give a good bearing for the supporting ring.

The bar shown under No. 3 is let into the walls at the ends and was riveted to the underside of the ring about one-third of the diameter from its front edge, leaving the bottom hole clear and allowing the ring to rest on the wiping, which thus supported the water by holding up the head instead of the shell. At the points where the ring would touch the house and range walls, short pieces of iron were fixed in the wall under the ring. In some jobs a second, shorter, bar was inserted under the ring across the corner back of the center.

The two round joints next the wall connect the copper range pipes leading from the water back to the lead-pipe connecting pieces. Two-thirds of the joint length, where copper and lead for hot service are united, is usually placed on the copper because there are frequent early failures in this class of joints through destruction of the bond along the copper surface. In distillery work, the life of the joint on copper to copper seems to be proportional to the length of continuous tinning on the copper and not to the compactness, thickness, fineness nor heat of the solder when wiped, the failure beginning at the end of the inner tinning and following the copper to the end of the joint outside as though produced by chemical action. In hot water plumbing joints on copper to lead the failure is probably due more to the slight shearing action consequent upon repeated unequal expansion of the metals in contact than to chemical action, though it is not clear how lengthening the joint would give any marked increase in length of service if the deterioration be taken to be solely due to the difference in coefficients of expansion for the metals affected.

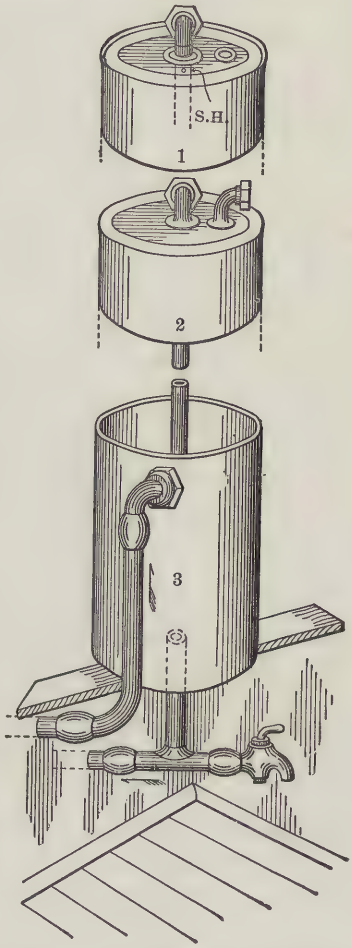


Fig. 491. Copper Storage Tank for Range,—with Heads Wiped In

The slop-sink of the job was a square pyramidal hopper of slight taper, mounted on a wood box pedestal. It was lead-lined and fitted with a separate hard wood rim. The lining formed up from the stock cut out as seen in Fig. 494 is shown sitting on the pedestal in Fig. 492. When so cut, only the corners have to be wiped. When the lining shape for a square sink is developed, like a deck flange, from an elevation of

the side, as **bcde**, Fig. 493, with **f** as a center to scribe the circles upon which to set off the other sides, at least three sides of the bottom and one corner must be wiped. It really makes a better job to wipe all the corners, if the sink is large enough to reach down in, for the lining can then be tacked in at all corners,—also, odd pieces of stock can in this

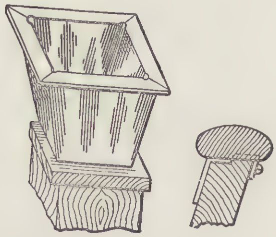


Fig. 492. Lead Lining Like Fig. 494 After Wiping, and a Section of Wood Rim for Its Case

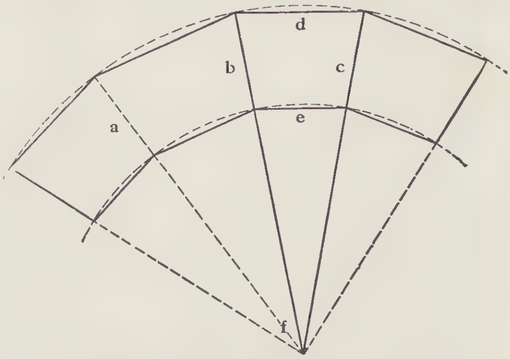


Fig. 493. Pyramidal Side-Lining

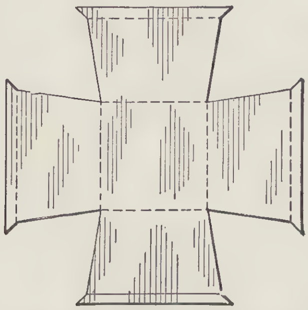


Fig. 494. Slop Sink Lining Cut to Wipe Corners Only

way be used up. No bull-eyes are necessary for slop-sinks of ordinary size. Residence sinks $20 \times 16 \times 12$-in., especially if with seamless corners, may be fitted with two spots front and two back, 6-in. from the ends, and one spot in the center of each end, all at the center of the depth. The closer spacing of spots in sinks than in attic tanks is called for on account of the dumping of hot water into the sinks.

The rim, shown in the side sketch, Fig. 492, is secured by angle clips attached to the bottom of the rim and screwed to the outside of sink, as shown.

The pan closet used in the job is shown in Fig. 495. It was supplied direct from the house storage tank by the pipe entering the side arm of the bowl. The cistern valve for the closet supply was placed in the main house tank and was operated by the closet pull knob,—a wire being attached to the lever and connected to the tank valve overhead by means of three bell cranks and a pulley. The cranks at the closet were first wired up and attached directly under the pull as shown, and as indicated in the separate sketch below the closet. This worked so far as bringing the water was concerned, but the movement of the cranks was too limited to allow the pan to drop. Slack in the lever connecting wire was next tried but the action was jerky, productive of lost motion, and altogether unsatisfactory. Perfect action was secured by bringing the wire obliquely from the back crank to the front and connecting the

upright wire to a hole in the lever between the fulcrum and pan arm at a point giving the wire sufficient movement while the pan was traveling through its complete arc. The bowl of the closet is earthenware, seated in putty, and projects down in the closet body enough for the semicircular pan to cup up over it in a way to make a water seal. The pull swings the pan down and back into the closet body by means of a shaft soldered to one edge of the pan and connected to the lever as shown: The pipe connection is a slip-joint, puttied, and wrapped with a cloth to harden the putty by absorbing its oil. The flush of all such

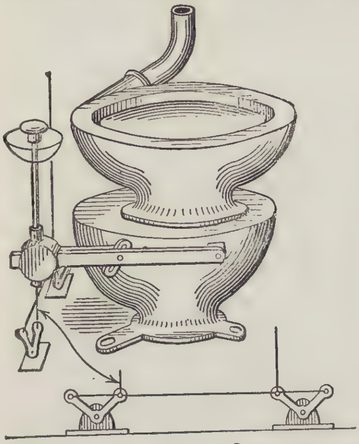


FIG. 495. PAN CLOSET OPERATED BY LEVER BELL CRANK AND WIRE

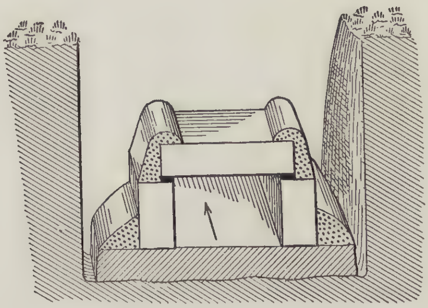


FIG. 496. HOUSE SEWER MADE OF ROCK, BRICK AND CEMENT

closets is a swirling action, more or less effective in scouring according to the pressure and volume of water. For the closet shown the people were instructed to hold up the pull until water reached the bowl.

Incidentally, it may be said that water will not swirl with good effect in any but round bowls. The most usual way of supplying such closets was through a time closing valve fastened to the front of the body and operated by a pawl or knee on the pull lever. All such so fitted or fitted as shown give only the after-wash. Seat action valves, generally speaking, give a continuous wash. Many old time closets with individual tanks gave fore-and-after-washes. Fore washing is now a thing of the past,—automatic periodic flushing being used where anything more than the ordinary after-flush is desired. The seats of old time closets were held up independent of the closet proper. Seat lugs, and pedestal support of the seat and person are comparatively modern.

No factory made drain pipe was used in this job. The entire house sewer from a lead end extending out through the house wall to a sinkhole 400 ft. away was a rectangular channel $6 \times 4\frac{1}{2}$-in. built up of brick and rock cemented together by the plumber about as shown in Fig.

496. The bottom and some of the top of the channel was made of flat rock about 2-in. thick, available near the premises and suitable in its natural state except as to width. The sides, throughout, and a portion of the top were made of brick.

Some fifteen years after this job was put in, the writer cleaned the channel. It was choked, mostly with grease, for 50 ft. or more at the house end. No growth had penetrated the channel and it was in good condition at a number of points opened along its length. On the same trip, the kitchen and slop-sinks were relined with sheet copper; the upper head of the storage tank rewiped; brass range pipe connecting pieces substituted for lead, and the closet valve rewired. It was not learned that any work had been done on the job in the meantime, other than faucet repairing, one renewing of the lead parts of the range pipes, and soldering a leak in the tank head.

A remarkable feature of this job was the utter absence of lead safe pans, for fixture safe pans were still almost universally used in most localities.

CHAPTER XCI

Country Gas Lighting Plants

In most localities piping for gas is a part of the plumber's regular work. The rules for city gas piping vary but little and are fairly well understood. In villages and country houses gasoline gas (carburetted air) is the most usual means of lighting where oil lamps are not used. The gravity of carburetted air is greater than that of atmospheric air, being free air plus the weight of gasoline vapor carried, while the specific gravity of city gas is about half that of free air. It will thus be seen that the greatest pressure is on the ground floor burners in a gasoline gas job,—just the reverse of the conditions in coal and water gas work. The city gas is "fixed." That of gasoline will readily condense more or less under slight temperature changes. Its greater weight reduces the flow and somewhat larger pipes are therefore required. The ease with which it will condense into a liquid demands greater care in piping so the system will drain. The drainage should be toward the carburetor wherever it is possible to so grade the pipe. Pipe for gasoline vapor should not be run in exposed places. Fixtures for it should have the keys at the lowest point; no pipe less than $\frac{3}{8}$-in. should be run, unless for a single opening on a short run. It is better to take the main riser to the top of the house and feed downward than to branch out for the different runs at their levels, because the friction of the larger line to the attic is less than that of a reducing riser and the supply when from the attic is partly by gravity. This plan is, however, not much practised as it requires connection from the low points in the floor runs to the main rising pipe in order to take care of condensation.

Many old buildings were not piped for gas at the time of erection. It is therefore necessary to do much piping in finished buildings in small towns and country work. This calls for skillful work on the part of the fitter as it is never the poorly built house that he is called to pipe for gas. The best way to take up flooring in such jobs is to saw off the ends at joists, beveling toward the piece to be removed; saw the tongue off on one side, then drift the board over so as to close the crack and saw the other tongue. When the board is put back the crack can be divided so it will not be noticed. Floor can be taken up and relaid so neatly in this manner, that the owner cannot tell whether it has been up or not.

Figs. 498 and 499 show the pump and carburetor of a gas machine job, Fig. 498 illustrating the pump, weight box and piping in the basement. As the wings of the blower drum are sealed by water it must be located where it will not be affected by frost. In the job shown all the

pipes, except dropping bracket lines, are graded to drain back to the carburetor in the yard. All fixtures have the shut-off keys at the lowest point, so that any condensation finding its way to the fixture arms can easily be taken out through the key.

Stop cocks are placed, as shown, on the main lines in the cellar in a convenient position. A bracket board just below the cocks holds them rigid. All fire-log, heating stove and range openings are supplied by an independent line taken from the illumination main but are not controlled by its stop cock. The bracket pipes in finished houses are run up or dropped down through partition walls and secured by boring screw holes through the lath at either side of the nipple hole. Wood screws are slipped through these gimlet holes in the lath and screwed into the ear-holes of the drop ells. The screws are selected, as to body size, so that the threaded stock will fill the earholes and make tight by drawing the ears of the fitting to the back of the lath. A clipped washer of considerable surface (finally covered by the wall plate) is used under each screw head.

The weight box is generally a round heavy sheet iron case with a heavy band riveted around the top. Its pulley stem passes through the bottom and is attached to a star or cross pieces to support the bottom and filling. A concrete weight will answer but makes it difficult to add or remove weight to adjust the pressure to suit the job. An ordinary residence job requires some 800 lb. weight in the box. This may be of boulders, broken stone, scrap iron or any other heavy material. The box should be geared up at least 8 to 1 with wire cable, so that the blower spool will pay out, say, 8-ft. of cable while the power weight drops 1-ft. The upward stress on the cable at the spool is reduced according to the number of sheaves at the weight. In the arrangement shown this stress is less than 100 lb. and is counteracted by a gas pipe standard from the rear front leg frame to the ceiling. The blower is screwed to the floor by wood screws run down in plugs drilled 2-in. into the concrete.

The various pipe lines are tagged with aluminum name strips, the designations being in raised letters and the strips strapped around the pipes just above the stop cocks as indicated at **C**, Fig. 498. These strips are easily and cheaply provided by punching them out on a nickel-in-the-slot vending machine.

One form of carburetor is shown in Fig. 499, connected and piped ready to fill in the earth. Carburetors are sometimes damaged in shipping, and *may* leak from defect, so it is best to test them under a little air pressure before covering, including with the carburetor all the piping to the cocks in the basement. On account of its shape a carburetor should not be subjected to as much pressure as is usually applied to the house pipes. Buckling of the heads is likely to interfere with

the stability of the mercury column in any case. The most that can be done is to lay some weights upon the head when the carburetor is in place and pump in 2 or 3 lb. pressure and let it remain some hours, even over night if convenient. If the mercury column is then anywhere near where it first stood, the carburetor and its piping may be taken to be tight. If there is a leak, there will be no air pressure after setting over night.

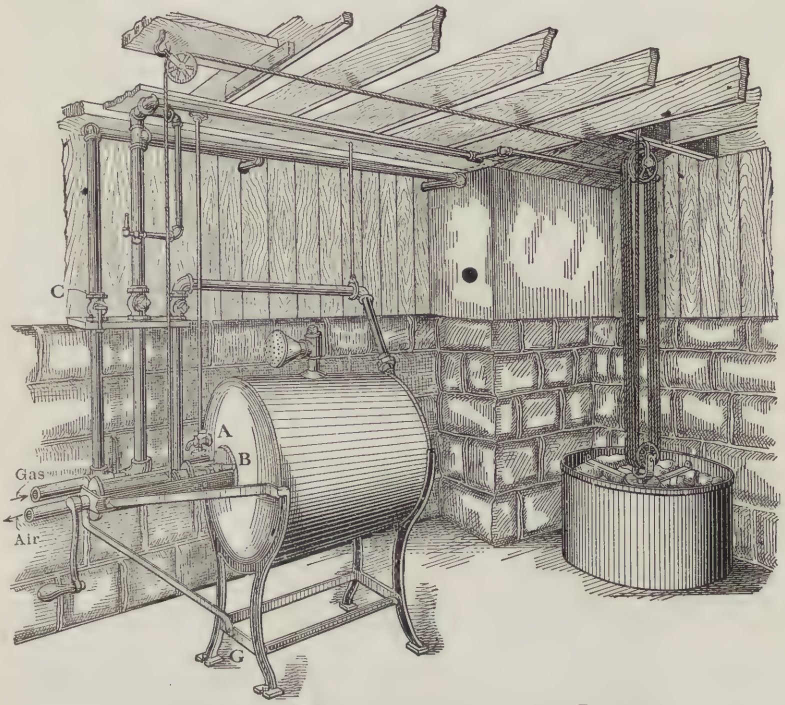


Fig. 498. Air Pump, Weight and Cellar Piping

In the carburetor shown, **A** is the fill pipe, **B** the gas supply to house, from which is extended to the surface, a vent pipe,—opened when gasoline is being poured in at **A**. **C** is the telescope standpipe for the float stem to work in. The air from the pump, in this machine, passes down the float stem which works through a loosely fitting stuffing box gasket. The weight of the float submerges its air holes and thus varnishes the air with gasoline. As the gasoline is consumed the float falls by its own weight. There are other forms of carburetors in which 70 to 120 sq. in. of gasoline surface or its equivalent are provided per burner. Fillings of charcoal, barriers of burlap and other material are used with the object of increasing the carburetting power possible in given dimensions. Where surface alone is depended upon numerous pans are placed in the carburetor in a way to overflow from one to

another. When fabric is added to these multiple surfaces capillary attraction keeps it saturated and the air passes through the meshes of the goods, so that the superficial surface of the liquid per burner may be much less than with plain surface.

Carburetors sometimes have to be taken up for repairs. It is therefore essential that both the air and the gas line have a coupling or union just outside the line of the carburetor wall. These couplings are indicated at **D**, in both the perspective view of the carburetor and the plan view at the right of it. There are several ways of joining pipes so as to give swing, some of which take less fittings than shown. Some fitters place the unions at **D**, instead of at **E**, but either couplings or unions must always be placed at **D**, so that the piping may be removed to a point that will permit the carburetor to be lifted out of the hole without further disturbance of the main lines.

It is best to dig the hole larger than will barely answer, so the carburetor may be shifted back and forth or to the right or left, according as necessary to make the connections meet easily. The particular advantage of having the connecting unions at **E**, is that settling does not tend to compress the washer on one side and open it on the other and thereby cause leakage as it would if settling took place with the unions placed at **D**. Every precaution should be taken to prevent the carburetor and pipe lines from settling. One can never tell beforehand what effect heavy rains or seepage will produce. The swing connections shown, all things considered, are probably better than any alternative arrangement.

If wood blocks are used to lower the carburetor on, they are sometimes hard to remove unless there is considerable room at the side. A better plan is not to use blocks but to make the bottom of the pit perfectly level, and then determine as near as possible where the chime of the drum will come and dig a ring for it to play in that will permit shifting if necessary. Next, with three or four $\frac{1}{4}$-in. wires, bent at the lower end as shown at **X** in detail sketch **K**, hooked under the chime, one person to each wire can easily lower any carburetor necessary for a residence job. When the carburetor has settled to place let the wires stand until the connections are made, so that shifting the position of the carburetor can be done by swinging it with the wires instead of forcing it with a timber. When the connections are made, if it is desired to remove the wires at all, it is only necessary to shove the wires down into a curve and give them a twist, as indicated by the arrow in the detail sketch, which will bring the bent ends out from under the chime.

It is better to never put gasoline in a carburetor before the pit is filled, as the warmth of the sun may generate enough vapor and pressure within it to rupture the metal. In summer it is sometimes difficult to

fill a carburetor at all unless every precaution is taken, as vapor is generated at ordinary temperatures and unless the package is filled from ground storage tanks, and delivered to the premises quickly and put into the carburetor promptly it will be so warm that it would be dangerous to close it up tight enough to put the machine into use.

If the package is not completely full, vapor space is left, and if it leaks at all, the more it leaks the more vapor space is formed, and the hotter it gets the greater the pressure within will be. A two-barrel steel drum lying in the sun an hour or two may develop such pressure as to cause leakage of the seams, and if a few gallons leak out, the vapor, when opened hot (a dangerous proceeding) will blow out from 1 to 4 minutes, according to the space and temperature within,—the pressure being very high for one to two minutes and making a frightful roar.

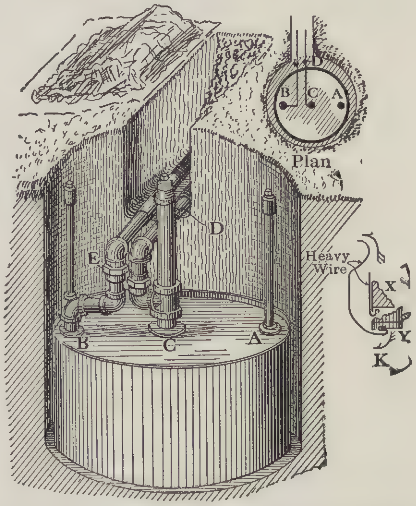


Fig. 499. Details of Storage Tank Work in Gas Machine Jobs

If the package has been recently agitated by rolling into place, the vapor will be mixed through the liquid; it may thus blow out much of the liquid contents with the vapor. The liquid will quickly change into vapor and fill the atmosphere for a good distance around. It is for this reason that care should be taken to have windows closed and fires and lights out when filling a tank. A breeze may carry vapor to the fire and cause ignition back to the package.

If a hot package is delivered or found to be leaking ever so little in warm weather it is the safer way to roll it into the shade, let it stand till the cool of the evening, then pour cold water over it until it is well cooled down; then roll it into position to fill, let it stand a while so that the vapor will find its way into the space above, and then syphon the contents into the carburetor as nearly as possible before turning the bung down.

If the apparatus is not to be put in service immediately, vapor pressure in the drum may be utilized to put the gasoline into the carburetor by using a piece of garden hose with a packer or rag wrapped around some 2 ft. from the end, so that the hose will reach low down into the drum. With this ready the screw can be removed, the hose poked down quickly and held close about the opening so as to retain

vapor pressure sufficient to blow part of the contents into the machine. When a carburetor is filled under these conditions one does not dare to close it for 2 or 3 days. The vent and fill pipe plugs must be left out of their sockets, so that vapor generated in the carburetor under the change of pressure will have a free exit, until the earth about has had time to cool the gasoline down to normal temperature.

Regarding the location of lights in a way to get the desired illumination: The fractional illumination (candle power) reaching equal space at varying distances is always denoted by a fraction having the square of the distance for the denominator, and 1 as its numerator. The direct light reaching a distance of 2, 3, 4, 5, and 6, at unit space (1 sq. ft. of surface) and distance (one foot) from the source of illumination is therefore only $\frac{1}{4}$, $\frac{1}{9}$, $\frac{1}{16}$, $\frac{1}{25}$ and $\frac{1}{36}$, respectively, of the falling upon equal surface at 1.

Reflection is dependent upon the color value and character of wall surface, which considered in the abstract may be anything from near zero to approaching 100 per cent. Direct reflection is in practice ordinarily taken at 50 per cent., which with the consequent endless reflections from interior walls may be, and generally is, taken as equaling the direct light, thus doubling the candle power due to direct rays, or say, for total illumination at 6, $\frac{2}{36}$ of the power at unit space and distance.

One candle power to 4 sq. ft. of floor space being considered ordinary, and one candle power to 2 sq. ft. of floor space being fairly brilliant illumination in ordinary rooms, what has been said will suffice for determining the position of the lighting fixtures,—bearing always in mind the purpose of the room and, making some safe assumption as to the power of the lights that may be used and the disposition of sources of light that will likely best accomplish the purpose with the greatest economy.

CHAPTER XCII

The Adaptation of Tools

To accomplish the work in hand with speed and ease a mechanic is often under the necessity of adapting his tools by grinding or forging and tempering. It is not always that he can command the service of others to do such work even though it be out of the ordinary to a plumber. Tool makers with skill in dressing tools to suit the work are not to be found in every quarter, especially if the shaping necessitates a personal knowledge that must have been gained by close observation or actual application of the tools to the work. In the absence of such ability, the plumber may find it difficult to explain clearly just what his knowledge conceives to be required and the work may be of too little moment to justify making sufficient drawings to illustrate.

So little skill and practice needs to be added to that which the plumber already possesses, that for the combined reasons given, it behooves him to make the effort at personal adaptation of his tools for all ordinary special occasions, for it is out of the question to always have at hand, if not to own, all the particular tools that may be used to advantage. The few points mentioned here and illustrated by the sketches in Fig. 500 will suggest the proper treatment in other instances too numerous to mention.

The most important point in keeping or making tools as one wants them is the little smithing involved, especially the tempering process, for without suitable temper the forging and shaping labor bears little fruit. It is generally taken as true that with ordinary tool steel, a tool must be reforged (hammered hot to close up the pores or grain) before it can be *retempered*, and it usually needs it for other reasons. The temper can be redrawn (drawn further) to make a tool softer without rehammering; to do so, the heat should be applied well back on the body, otherwise the softer part will likely be merely a skin of soft metal over a hard core—a very unsatisfactory result because the degree of hardness, for any tempering a plumber will do, is judged by the color, and the color would be false for the mass,—representing only the outer layers receiving the heat most readily.

The colors which tempers are drawn to, and the Fahrenheit temperatures said to represent them are:—for cutting tools; the second marked degree of hardness, next to the hardest possible, is straw. The hardest possible, such as file hardness, and that of gravers for hard metals' is obtained by heating, the steel uniformly to a cherry red and cooling in water,—the color so obtained may be termed *white*. Upon reheating,

the colors and successive degrees of hardness appear in the following order: Straw 430 deg. F.; dark yellow, 482 deg. F.; brown 500 deg.; purple reddish, 525 deg.; dark reddish, 550 deg.; blues, ranging from 570 to 635 deg. F.,—the latter being a greenish hue. Nothing softer than blue will be needed by a plumber. Straw is good for wood tools, except for gouges like **R** and for wood and floor chisels with steel shank, like **F** and **P**, all of which are subjected to considerable prizing and therefore if too hard are likely to snap off when used as a lever, and are most certain to "gap" or lose a corner if a nail is struck.

A plumber does so much cutting in finished work, that he finally comes to take a savage delight in cutting nails with edge tools. The chewing up of a nail or so, with a wood chisel or gouge, in a pipe-hole, is rather expected, and nothing short of seven nails in one hole can make a plumber swear.

Higher colors than straw answer for brass, cast and wrought iron, granite, limestone and brick, the hardness of tool suitable running from soft for brass to hard somewhat in the order in which the materials are mentioned.

Other colors and temperatures are: 960 to 970 deg. at which annealing begins; 1470 deg., cherry red; 1825 deg., light red; 2375 deg. glowing white, and 2550 deg., a welding heat.

Forging to the precise form is not necessary,—considerable filing and grinding may be done, according to the job, facilities, and the degree of skill of the workman. A forge fire is not requisite for a small job,—a heating stove, range fire, charcoal furnace or gasoline blast will often answer as well. Steel is easier "burnt" than iron; should not be heated so hot, and will shape under the hammer at lower temperatures. Quite a little smoothing and compacting can be and is as well done after the red heat has disappeared. The general drawing out and shaping should be practically done at red heat. A light red is as hot as any chisel reworking should be commenced with. Breaking down or denting deep or acutely with the hammer should be avoided,—dents, though apparently dressed out, often furnish a slight cold lap or "shut" which ends in the breaking of the chisel through the shock of blows ever deepening the fracture. Of course a regular anvil is best to work on, but a vise-anvil, an old flat-iron clamped in the vise, a scrap of eye-beam or railroad rail will answer for odd jobs.

Supposing a chisel ready to temper, it may be heated and plunged slowly straight down into water until cool, and the temper drawn back to the softness required, as before mentioned, but this is not the ordinary practice. Time is saved by partially cooling and then allowing the initial heat yet contained in the stock to draw the temper as desired. This is more difficult to do with good results than usually supposed and

many chisels have soon needed reshaping for lack of temper depth. One may expect failures from this style of tempering. Even after being deemed proficient in the art, a chisel from a different size of steel may cause trouble from not correctly judging the amount and position of interior heat left in the stock with which to draw the temper. The depth of submergence, distance the point is at first dipped to begin the cooling, how fast or slow the stock is next lowered, and how nearly the whole is apparently cooled off, are all matters of personal judgment depending for good results, upon size of stock, shape, length and stock of

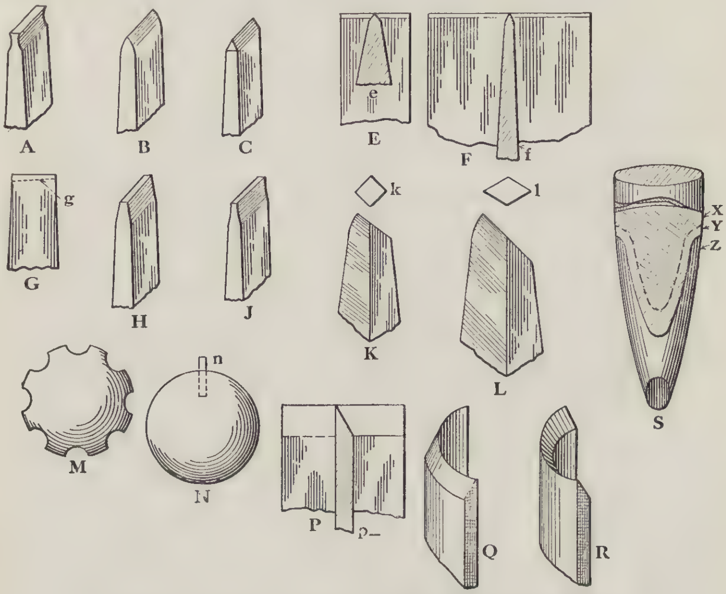


FIG. 500. STEEL TOOLS—THEIR FORM AND TEMPER

the tool end, etc. The object of partially cooling, and not lowering the tool to the ultimate depth immediately is to leave a core of hot metal within, more or less nearly approximating the shape of the outer contour as indicated in sketch **S**, with a view to bringing the proper color and temper to the cutting edge and adjacent metal by conduction, without backing it up with stock too soft to stand and without running the color desired ahead of the necessary interior softening. If the heated part of a chisel, cooled preliminary to drawing the temper, could be seen its section would look something like the hatched and cross-hatched cones **X** and **Y**, sketch **S**,—**Z** standing, in the sketch, for the portion to be softened by conduction. When a chisel has been cooled, the scale and oxide on the surface should be rubbed off down to clean metal with a piece of brick or rock, so the color of the body of metal can be watched. A fault with beginners is that they are given to drawing temper too quick,—

too much heat being left in the stock. For a stumpy point on $\frac{3}{4}$-in. stock, the stock can be so nearly cooled that 5 to 10 minutes may be required to draw back to a dark blue at the point,—a tough point resulting, hard enough to "pitch" hard lime-stone without breaking.

R in the sketch shows a steel gouge beveled from the inner face intended for cutting supply pipe holes with parallel sides,—a hard job with a gouge ground regular, as at **Q**, if the hole is close to the wall so the handle of the gouge cannot be leaned in all directions, and, impossible with **Q**, if the thickness of the floor exceeds 1 in. **P** shows a wood chisel blade, beveled from one side: **F**, a thin wide "floor" chisel blade, slightly beveled from both sides like the ordinary cold chisel shown at **E**. The small letters on these sketches mark sections in alignment with the blades.

K represents the end of a diamond point. The tapering part is with square stock like the cross-section at **k**; another point is shown at **L**, with stock above the point more or less acute as at cross-section l. The frustrum of these chisels are generally forged square, but may be made or afterward ground to either acute or obtuse, section, as best suits the work in hand. The heel curve of the point (seen on the left at the end) is ground more or less pronounced, according to the angle the chisel must be held at to keep it from "digging" or running out. The curvature may need to be specially suited to the surface to be worked on,—that is, for ditching flat, concave and convex surfaces the heel requires to be ground differently for each. Without changing the shape of the cross-section of the point, the angle of the cutting edges can be changed to more obtuse or acute in two ways,—in grinding the heel or by increasing or decreasing the angle of the face to that of the frustrum. For some work, such for instance as cutting off a 3 to 8-in. wrought pipe by hand, the angle of the cutting face may need changing within an hour or so, unless there is more than one diamond point in the kit, because; the thickness of metal is too great to attempt at one cut and great speed is made by first taking a cut around with an obtuse point and next cutting the middle out of its ditch with an acute angled point.

It should be kept in mind that the chisel used should be in proportion to the work. A chisel too large absorbs too much of the shock of the blow and transfers too little of the energy to the work. For chipping and channeling or other work not requiring a heavy lick, a short keen chisel will stand the shock and remove much more metal with less labor than can be moved with a heavy chisel.

A suitable screw driver is a tool probably the least likely to be found in a kit; there is seldom more than one in a jobbing box, and the range of screws it is applied to would seem to require several or one handle with several blades. **B** is the form many old blades are found

to have, and **C** shows it beveled from the edges to reduce the width for small flush screws; it requires great labor to hold **B** in the slot, as when twisting it endeavors to ride out. **H** is the form on most new blades,—slightly tapering at the sides which, if the driver is held straight, engage the slot only at the face of the head and increase the tendency to split it. **J**, with parallel lips, is better, as whether loose or tight, the sides will partially engage the slot the full depth. Sketch **A** shows a blade with slightly concaved lips, a form that *never* slips, though it may shear the head off of the body,—if not too hollowing there is little danger of this, as the lips may engage the slot at both top and bottom. The author does not attempt to keep a blade in the shape of **A**. One handle with a nest of blades will serve, so long as the blades are at hand when needed, but, ordinarily, one long blade tempered soft answers for all but close corners not admitting its length; for regular work it is filed or ground to "**J**" shape, thin enough for all common screws; for hard work or removing old screws, it is quickly battered into "**A**" shape with the hammer, so it won't slip; if slots are next encountered that are too narrow, the curve of the lips is filed off, reducing it to "**J**" shape again; if heads are small, it is beveled from the edges as indicated at "**C**". Where old screws are hard to remove it is often because the heads were ruined with an unsuitable blade when they were put in. It is not that old screws are always so hard to take out as supposed, but that the slots are filled, and the blade of the driver does not fit.

If heavy work must be done with a short driver it will aid much to lean the driver, with the slot, out of alignment enough to get sufficient leverage to turn the screw easily. If the angle at which the screw turns is great enough to bring one edge of the lip near the top of the slot, file the end of the driver out of square as shown at g, in sketch **G**. In driving a screw the fingers act as a series of hands pulling on cranks with handles at the radius of the driver handle,—leaning a driver increases the crank radius as may be inferred from **N**, **n** being the end of blade at the screw, **N** the handle surface, and the whole driver a crank of increased throw. It is an advantage to flute the handle as at **M**,—the fingers then engage the flutes as a series of pawls would the teeth of a ratchet, and the work is accomplished with less gripping.

CHAPTER XCIII

The Plumber's Interest in Odd and Special Castings

When it is to the interest of a plumber to have some special casting made, as it often is, he will find the foundry item of pattern making most expensive. The foundry can have but one high standard for patterns or other work and may be almost limited, in facilities, to its usual output. The pattern maker knows nothing of the circumstances under which a special article will be used; his work is worth what he charges and its quality maintains his prestige as a fine workman. The foundry too, has some incentive to live up to the limit on odd patterns and castings. The high cost of special work inspires respect for the staple goods at *their* price, and unless prepared for miscellaneous work the confusion caused by an odd job is not actually repaid by even an exorbitant price. So, as the plumber has the work in hand, knows what variations from the ideal are permissible, what type or grade of finish will serve the purpose, etc., he can select a maker who is prepared, or perhaps make the pattern himself at a minimum cost. A canvas of the articles and their parts in general use in the allied trades will frequently discover some market piece that can be easily adapted by a little drilling, grinding or lathe work; if not adaptable for direct use, possibly puttying up some holes, shaping, gluing on a boss or extension of some sort will make it answer for a pattern. Some articles are best and cheapest fashioned direct from the metal without a pattern; others may have features that are best shaped in the casting (when only one or two are to be made) rather than to try to approximate the finished article too closely in the pattern. When a pattern must be made outright, strict regard must be paid to the fact that a pattern has to be withdrawn from the sand to leave the cavity for the metal and that parallel sides, and parts overhanging the line of "drawing" will not allow the pattern to come out without breaking the walls of the mold; a little taper of all sides in one direction (that from which the pattern is to be lifted) is therefore necessary. Unskilled hands can not shape delicate pieces in wood so easily, and soft metal is sometimes better than wood for the pattern. White pine wood is generally used; any kind may be used for an odd casting; the finish depends somewhat upon what the casting is to be used for; the varnishing of the pattern may be left to the founder who makes the casting.

If a pattern is of pine, the weight of the casting may be found by multiplying the weight of the pattern by 19 for lead castings; by 14.4 for zinc; by 13 for brass; by 12.2 for tin and by 12 for cast iron.

Allowance for both the shrinkage of a casting and the finishing of it must be made in the dimensions of the pattern. Finishing margin is governed by the kind of work; metal shrinkage by the kind of metal and type of casting; in some instances shrinkage need not be allowed; for example, the length in some house columns in which, when pouring the thrust of the iron extends the cavity length equal to the shrinkage in length. Nothing of this sort is likely to be contended with in any casting that a plumber will ordinarily have to do with. He can safely make the following allowances for metal shrinkage: For brass and iron $\frac{1}{8}$ in.; for zinc, $\frac{5}{32}$ in.; for tin, $\frac{1}{12}$ in., and for lead, $\frac{1}{4}$ in. per linear foot.

Table XXXIII. Component Metals of Alloys

Alloys	Component Parts						
	Copper	Zinc	Tin	Antimony	Nickel	Lead	Bismuth
Babbitt metal	3.7	....	89.0	7.3	....		...
Brass, ordinary	84.3	5.2	10.5	...	....	....	...
Brittania metal	10	5	25	60	....	....	...
Bronze, red	87	3	10	....	....	....	...
Gun metal	90	....	10	....	....	....	...
Bells, church	80	5.6	10	....	....	....	...
German silver	33.3	33.3	....	....	33.3	4.4	...
Bearings, machine	87.5	12.5	....	....	....	....	...
Metal that expands while cooling	....	....	....	167	....	75	8.3

Solders	Component parts							
	Gold	Silver	Copper	Brass	Zinc	Tin	Lead	Bismuth
For 14K gold or finer	(Same caret) 1 pwt.	2 gr.	1 gr.	....	....	...	....	....
For 12K gold or less	(Same caret) 1 pwt.	....	....	....	2-gr.	...	....	....
For gold, ordinary parts	18	4	5	...	2	...	....	....
For silver parts	....	18	4	....	1	...	....	....
For silver (white)	....	1 oz.	....	....	30 gr.	...	....	....
For brass (hard)	....	....	3 oz.	2 oz.	....	5 oz.	....	....
Spelter solder parts	....	....	50	....	50	....	....	....
For tin parts	....	....	....	....	....	60	40	....
For pewter parts	....	....	....	....	....	40	20	40
For platinum parts	....	(pure silver)	....	....	....	...	....	....

A list of such common alloys and their component metals as may be thus brought to vitally interest the plumber at times, and also some solder alloys not in every day use in the trade are given in Table XXXIII:

Alloys vary in the percentages of their component metals according as they are made up with a view to use for a specific purpose. In making brass for lathe finishing, a little lead is generally added.

Solders may also be varied to suit the particular work in hand, according with the judgment of the workman as to whether greater or less fluidity, conductivity, etc., are likely to aid in combating the characteristics of the metal to be soldered. Aside from cleanliness of surfaces, having the proper flux and the right kind of solder, a vital point to sound smooth work lies in getting the surfaces to be soldered as hot or

hotter than the fusing point of the solder used. It is for the above reasons that beginners cannot spend too much time in studying a table of the characteristics of common substances for the purpose of fixing in mind the relative conducting power, specific heats, etc., of metals that have to be soldered as well as those that enter into the composition of solder. Such knowledge is necessary to avoid getting indifferent results when successful work is most desired and would reward the effort but for ignorance of some easily acquired foresight bound up in such data.

Referring back to the main topic, again: in remote districts, one may be called upon to, or have the opportunity to do almost anything imaginable. In case of emergency, any of the metals with the higher fusing points, of the alloys given, may be melted,—enough to make thirty to fifty pounds of brass if necessary, by using a crucible in a blacksmith fire. For such heats, a good fire of coked coal of a good quality, practically enveloping the crucible, and well banked in by a thick wall of wet slack, is necessary. Three hours or more of hard blowing is then likely to be required to get a "pouring" heat.

CHAPTER XCIV

The Profit End of Business

Profits are the most interesting factor of the business and yet the subject will draw an irritable reply quicker than any other,—proof that more needs to be said. The author can speak here, probably with good effect, because he is not competing with the reader for business and is grinding no axe in the way of indirectly raising the other fellow's price in order to get the job for himself, and the reader can't talk back, before thinking, to the effect that fools know their own business better than wise persons know other people's. Then too, the author has, as will be shown, no plea to make for bold inconsistent prices and has personally been all along the line; has met, smiled at, shook hands with, worked for an finally cussed the flock of parasites who seek every new comer as an aid to living by dodging honest debts; has turned away the good looking proposition with uncertain pay behind it; has learned to beware of the architect who muddles or provisos his specifications into a conundrum, because, either he will beat you at his game, or don't know enough to keep some fellow who will stoop lower than you, from beating him, and that same fellow will, for the purpose, bid too low to make your bid worth while; has learned not to take the work at the other fellow's price,—both had the same chance, and the job is his and, in all these cases your bid *may already* be the *lowest* and the patron trying to profit by your foolishness; has learned not to furnish the goods at cost and throw in the work gratis on contracts and then charge too high for day work jobbing to make up for it; has handled the business on short capital and camped on the door-steps for pay to make ends meet; has handled the big job with too little capital and paid interest on over due accounts, and divided the profit with the bank for money to meet the payroll, but never yet agreed to do a job for a poor price. Experience lends the authority of experience to these statements, and the following: A price is like religion,—you must have faith in it and charge of your own free will because you know it is right,—then you are safe. An evangelist can literally drive a lot of people without faith into a church membership, but at the first opportunity they drive themselves out again. So he has the job eternally on his hands. A man who charges without faith will cut prices without cause, and if one cannot see that a certain profit is necessary in order to stay in the game with credit to himself and the business, and to provide against disaster that is certain to come unless there is a surplus above mere existence, he is likely to take the chance on a meager profit, too long.

There is no occasion to preach to the man who is doing a good business, built up at a healthful rate; he has had the experience, directly or indirectly; the only thing worrying him in this connection is the ill effect on the public through seeing a wide range of prices without knowing the whys and wherefores. Prices that are too low, not only finally kill the perpetrator but reflect on the man who charges an adequate price, keeps the standard of performance and dignity of capability down, and point out, very generally, the class not sufficiently acquainted with the calling to make their work a credit to it.

A thorough business man knows what it is costing him to do business. A beginner cannot know from the start, but he is safe in assuming 25 per cent. The less business the higher it is; close watching and sensible conduct will bring the cost to the neighborhood of 15 per cent. for an established business. The horse and wagon, or automobile for a city shop is debatable: the hire must reach $1.00 per day average before it pays to own and maintain the cheapest possible outfit; location, as it affects rent, depends on circumstances; a high rent in the zone of heavy travel may not pay in a particular instance, so far as profit in vending to shoppers is concerned, but may be advisable on account of time saved, especially if the business is largely contract work. No elaborate show of fixtures will pay if there is a public show-room close.

An array of profit, cost of operating and net return decimals cannot be compared in a way to produce the best effect on the mind of the person most in need of aid. They are truth in the abstract but do not alone show the kinship of any business to any net result. They cannot be individually applied in print form,—this must be done by the proprietor or his agent.

Probably the best thing that can be said is to consider some of the things true of the modest beginner's problem. If he gets the work, does the work, keeps the books, makes out the bills and collects the money, either he will do little business or die soon. If he is to make no more than a journeyman it is better not to have the responsibility and to keep the savings safe and make that much in 8 or 9 hours instead of 18. By any other course, it will shortly come to the following, at least:—one journeyman, $21.00 per week; 1 helper for same, dividing his time with the Boss when necessary, $4.00 per week; one boy to stay in the shop, answer phone, enter orders, etc., a sort of all-round clerk, $6.00 per week; telephone, light and fuel, $2.00 per week; rent, $4.00 per week; Boss' time at journeyman's rate, $21.00 per week; total $58.00 per week in excess of the material bills, that must be earned, *none* of which can be called profit on *investment*. What is required to *get this* amount. The Boss will make, say half effective time; cost of man and helper 50 cents per hour; charged per hour, 75 cents; profit on effective time, 50 per cent. Cost of the effective time, say $37.50; profit on same

$18.75; total, $56.25; difference,—deficit, $1.75. This assumes there is work on hand to be done; it also assumes that 50 per cent. profit is made on labor for all the time any of the force is engaged on contract work; this in time implies that 50 per cent. profit on time was figured in the estimate, and that the work is progressing in accordance with the estimated time. Actual non-effective time is a bigger factor than above allowed. At the utmost the force named cannot hope to use more than $200.00 worth of material per week in busy times, and the average would be about $100.00 per week for the year, allowing for the usual amount of job work; say $8000.00 all told for the first year's business, which can be done on $1000.00 combined stock and working capital. Add the interest on investment to the deficit as figured above; it makes, say $3.00 per week; for any liability insurance, scrap and breakage at $2.00 say altogether, 5 per cent. of the weekly material bill. The goods will average at least 30 days in hand to the transaction, from the time the plumber is liable until installed and paid for, so, not less than 20 per cent. of the cost of goods must be added and *collected* in order to permit the Boss to get out of the business, as above outlined, even as much as he pays his journeyman. Not more than 20 per cent. for the average deal-period can be expected from the material source; the labor at 50 per cent. profit does not pay all the cost it involves. Where, then, is the Boss to profit more than one of his men? There is only one reasonable way to do it, and that is to *do more business.* This can be done without altering the fixed expenses, like rent, personal time, phone, etc., so the rate of profit increases with increased business without advancing the cost to patrons.

The percentage labor is of the total cost of work has to do with fixing a flat rate of profit, if such is employed. If the labor at 50 per cent. profit on a $312.00 cottage job be taken as $120.00 ($80.00 being labor,—$\frac{1}{3}$ *cost* of job), and the material at 20 per cent. as $192.00 (160 dollars being the cost of material), the labor profit is $40.00 and the material profit $32.00; total profit $72.00—a mean profit of 23 per cent. on the selling or 30 per cent. on the cost of the job. This indicates, and it is true, that a 30 per cent. flat rate added to the *cost* of *labor* and *material* is a fair estimate on ordinary contract work. It is best, however to fix the labor separately at a price that will cover non-effective time and also bear its proportion of, say 20 per cent. profit on the cost of time worked. This is only another way of saying that the whole time costs at the same rate and that the profit on the effective time, usually 50 per cent., should pay 20 per cent. on the effective time, and the *cost* and *profit* too on unavoidable non-effective time,—not chargeable, however lost.

Table XXXIV shows profits on costs and will aid in fixing upon the price, or discount to be given from the list price purchased by:

To use Table XXXIV: A bath room mirror cost 40 per cent. off of an \$8.50 list; it is desired to make 33½ per cent. profit on the cost; the table says sell at 20 per cent. off the list. Proof: at 20 per cent. off, 80 per cent. will be received; therefore the list multiplied by 0.80 will give the selling price,—$8.50 \times 0.8 = \$6.80$, the selling price of the mirror to make 33½ on the cost. $8.5 \times 0.6 = 5.10$, cost; 6.80 (selling)—5.10 $= 1.70$, profit; $1.7 \div 5.10 = 0.333$ per cent.

The smaller the item, the greater the per cent. profit should be. If the prize per dozen with fair profit, is \$3.00, sell *one*, for 30 cents,—*one-tenth* of the dozen price.

Table XXXIV. Per Cent. Profit on Sales

Bought at Discount from List	Sold at Discount from List	Profit per cent. on Cost	Bought at Discount from List	Sold at Discount from List	Profit per cent. on Cost
0.10	List	0.11	.45	.17½	.50
.12½	List	.14	.47½	.30	.33
.15	List	.17	.47½	.21¼	.50
.17½	List	.21	.50	.40	.20
.20	0.10	.12	.50	.35	.30
.20	.05	.18	.50	.30	.40
.20	List	.25	.50	.12½	.75
.22½	.10	.16	.52½	.40	.26
.22½	List	.29	.52½	.28¾	.50
.25	.10	.20	.55	.43¾	.25
.25	.02½	.30	.55	.40	.33
.25	List	.33	.55	.32½	.50
.27½	.10	.24	.57½	.45	.29
.27½	List	.38	.57½	.35	.53
.30	.12½	.25	.60	.50	.25
.30	List	.42	.60	.40	.50
.32½	.15	.25	.60	.30	.75
.32½	.10	.33	.62½	.55	.20
.32½	List	.48	.62½	.50	.33
.35	.18½	.25	.62½	.43¾	.50
.35	List	.53	.65	.56¼	.25
.37½	.25	.20	.65	.47½	.50
.37½	.10	.44	.65	.38¾	.75
.37½	List	.60	.67½	.57½	.30
.40	.25	.25	.67½	.51¼	.50
.40	.20	.33	.67½	.42½	.76
.40	.10	.50	.70	.62½	.25
.40	List	.66	.70	.60	.33
.42½	.25	.30	.70	.55	.50
.42½	.13¾	.50	.75	.70	.20
.42½	List	.74	.75	.62½	.50
.45	.30	.27	.80	.75	.25
.45	.25	.36	.80	.70	.50

The prices of plumbing goods never were and never will be high enough to give the master plumber more than a fair profit. We pay a shoe man 100 per cent. profit about four times per annum, from year to year; he buys one bath tub at 20 per cent. profit to us,—never buys another and talks about the calling the balance of his life. It is the same with many other lines. They charge, and talk to divert attention from themselves, while plumbers as a class are too poor and too busy to talk of anything but work, and never having experienced a liberal profit do not realize what all the fuss is made for.

END

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